AUDIO · RADIO · COMPUTERS · SPACE · REVIEWS

No. 73
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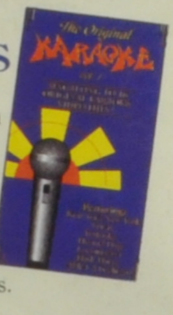

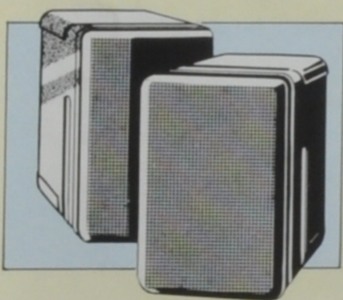

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JANUARY 1994
VOL. 13 No. 73

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PROJECTS *FOR YOU TO BUILD!*

TWILIGHT SWITCH 8
A versatile project, with numerous applications, that senses the ambient light level. The output switches at dawn and dusk; so when it is used to control night-time security lighting it is more energy efficient than a time-switch.

MILLENNIUM 4-20 Hi-Fi VALVE AMPLIFIER 24
It's what everyone has been waiting for – the most exciting Hi-Fi project for years! This top quality amplifier can be built in several configurations and sounds just great! It looks pretty impressive too!

418MHz FM RADIO LINK 40
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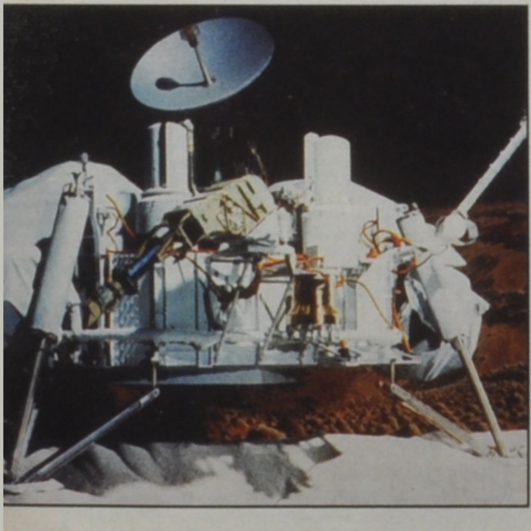

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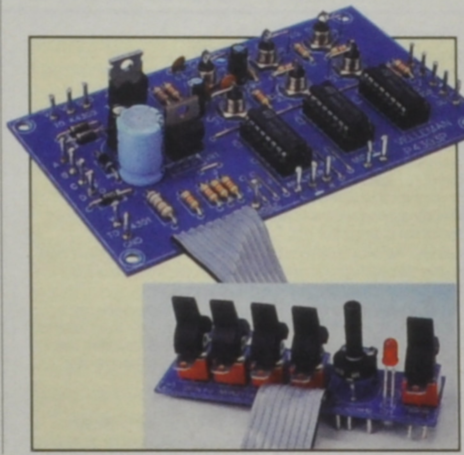

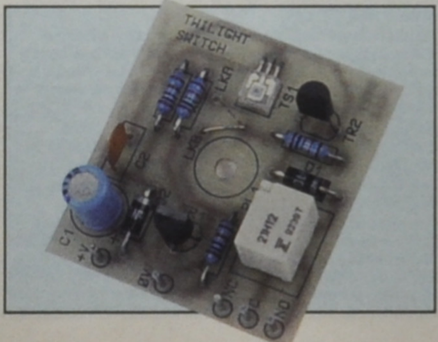

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REGULARS *NOT TO BE MISSED!*

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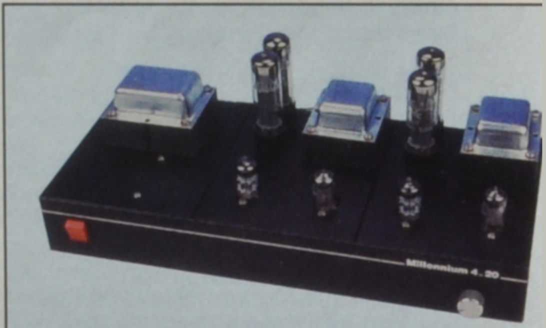

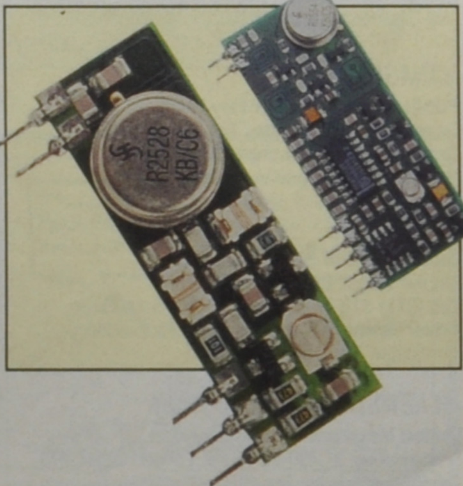

ABOUT THIS ISSUE . . .

Hello and welcome to this New Year's issue of *Electronics*!

As you will no doubt have gathered from the cover of this issue, the Millennium Amplifier graces us with its appearance. The first half of the project, the power supply, is presented this month and the concluding half, the audio power stage, is presented next month. This project represents a double first for Maplin Electronics and *Electronics* magazine; it's the *first* fully blown valve project we've published and made available as a kit. You may or may not subscribe to the 'valves sound better' theory, but either way you can easily dip a toe in the water with *this* project since all of the components are readily available, both in kit form and individually (see we *do* listen to your requests!). We've been careful to watch the £££'s too, you probably won't find a commercial valve amplifier at such a reasonable price elsewhere! Since the design is modular, with separate power supply and audio power stages you can easily tailor the final version to suit your own requirements; mono, stereo, stereo from two mono-blocks, quadraphonic – the choice is yours! You can build the amplifier in stages to suit your pocket, with the option of upgrading later if you wish.

What does the Millennium sound like? Well, I personally like how it sounds, and it certainly looks far more interesting than the usual black or silver square box-amplifiers that are the current norm. But, the final opinion is down to you and your ears! Please write in and tell me what you think (good or bad). You never know, this could start a new trend for valve based projects. . . .

Even if valve amplifiers leave you completely cold, there's plenty of other projects and features in this issue to keep you entertained throughout the cold dark winter nights.

Reviewed in this issue is a new software package called *Electronic Principles*, it runs on an IBM PC or compatible (sorry Atari/Amiga users!) and provides a comprehensive introduction to electronics theory. Because it makes use of interactive graphics, it's a far more interesting way of learning than reading a reference book; of course books do still have an important role to play in any learning exercise. Component values, voltage levels and signal amplitudes can be entered, the results are then shown on-screen in animated form. Turn to page 4 to find out more! As a special offer, exclusive to *Electronics'* readers, you can save £5 on the purchase price of the package. To take advantage of the saving, simply quote '*Electronics – The Maplin Magazine* £5 Discount' when you order, the offer is open until 31st December 1993 (please note that *Electronic Principles* is not available from Maplin).

If you've ever wanted to add a radio link to a project, then the 418MHz Radio Modules' Data File will be of interest, it explains how to use the modules and gives a whole host of versatile applications circuits which can be adapted to suit your needs. The ready-built modules are completely pre-aligned, so they are really easy to use – even if you've no previous experience with RF circuits. The modules are MPT1340 approved and don't require a licence to use – what more could you want?

Of course, there's lots more to read and build, as well as the things I've mentioned, so go on!, what are you waiting for?, start turning those pages!

CORRIGENDA FOR ISSUE 72 / DECEMBER 1993

Medusa Infra-Red Remote Control Extender
Page 18, Figure 2a: The 10µF capacitor adjacent to IC2 is incorrectly marked as C1, it is in fact C4. Additionally, the polarity of this component is shown reversed. The PCB legend is however, correct.

Page 21, column 3, line 6: '0·5A' should read '0·25A'.

Quizzer Priority Quiz Buzzer
Page 33, Figure 2 and Page 36, Parts List: IC3 is shown as a ULN2801A, whereas it should be a ULN2803A (QY79L).

Page 34, Figure 3 and Issue 1 PCBs: RG1 is shown on the legend with incorrect orientation, RG1 should be fitted as follows: align the RG1 with the legend, rotate it through 180°, so that the flat face of the regulator is facing away from the flat side shown on the legend, then fit. Issue 2 or later PCBs are correct and RG1 should be fitted as shown on the PCB legend.

PLEASE NOTE
Should VAT rates have changed in the November '93 Budget, prices will change to reflect the new rates.

Front cover picture:
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Maplin Electronics PLC.
The golden age of valve amplification returns with the Millennium 4-20 Valve Amplifier.

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Project Ratings

Projects presented in this issue are rated on a 1 to 5 for ease or difficulty of construction to help you decide whether it is within your construction capabilities before you undertake the project. The ratings are as follows:

1 Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering iron, side cutters, pliers, wire strippers and screwdriver). Test gear not required and no setting-up needed.

2 Easy to build, but not suitable for absolute beginners. Some test gear (e.g., multimeter) may be required, and may also need setting-up or testing.

3 Average. Some skill in construction or more extensive setting-up required.

4 Advanced. Fairly high level of skill in construction, specialised test gear or setting-up may be required

5 Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

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Kits, components and products stocked by Maplin can be easily obtained in a number of ways:

Visit your local Maplin store, where you will find a wide range of electronic products. If you do not know where your nearest store is, refer to the advert in this issue or Tel: (0702) 552911. To avoid disappointment when intending to purchase products from a Maplin store, customers are advised to check availability before travelling any distance.

Write your order on the form printed in this issue and send it to Maplin Electronics, P.O. Box 3, Rayleigh, Essex, SS6 8LR. Payment can be made using Cheque, Postal Order, or Credit Card.

Telephone your order, call the Maplin Electronics Credit Card Hotline on (0702) 554161.

If you have a personal computer equipped with a MODEM, dial up Maplin's 24-hour on-line database and ordering service, CashTel. CashTel supports 300-, 1200- and 2400-baud MODEMs using CCITT tones. The format is 8 data bits, 1 stop bit, no parity, full duplex with Xon/Xoff handshaking. All existing customers with a Maplin customer number can access the system by simply dialling (0702) 552941. If you do not have a customer number Tel: (0702) 552911 and we will happily issue you with one. Payment can be made by credit card.

If you have a tone dial (DTMF) telephone or a pocket tone dialler, you can access our computer system and place orders directly onto the Maplin computer 24 hours a day by simply dialling (0702) 556751. You will need a Maplin customer number and a personal identification.number (PIN) to access the system. If you do not have a customer number or a PIN number Tel: (0702) 552911 and we will happily issue you with one.

Full details of all of the methods of ordering from Maplin can be found in the current Maplin Catalogue.

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Prices of products and services available from Maplin, shown in this issue, include VAT at 17·5% (except items marked NV which are rated at 0%) and are valid between 3rd December 1993 and 28th February 1994. Prices shown do not include mail order postage and handling charges, which are levied at the current rates indicated on the Order Coupon in this issue.

Technical Enquiries

If you have a technical enquiry relating to Maplin projects, components and products featured in *Electronics*, the Customer Technical Services Department may be able to help. You can obtain help in several ways; over the phone, Tel: (0702) 556001 between 2pm and 4pm Monday to Friday, except public holidays; by sending a facsimile, Fax: (0702) 553935; or by writing to: Customer Technical Services, Maplin Electronics PLC., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Don't forget to include a stamped self-addressed envelope if you want a written reply! Customer Technical Services are unable to answer enquiries relating to third-party products or components which are not stocked by Maplin.

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If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker ideas; Mini Circuits or other similar 'building block' and 'application' circuits. To take advantage of the service, return the complete kit to: Returns Department, Maplin Electronics PLC., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Enclose a cheque or Postal Order based on the price of the kit as shown in the table below (minimum £17). If the fault is due to any error on our part, the project will be repaired free of charge. If the fault is due any error on your part, you will be charged the standard servicing cost plus parts.

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£60 to £79.99	£40
£80 to £99.99	£50
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Over £150	£60 minimum

Readers Letters

We very much regret that the editorial team are unable to answer technical queries of any kind, however, we are very pleased to receive your comments about *Electronics* and suggestions for projects, features, series, etc. Due to the sheer volume of letters received, we are unfortunately unable to reply to every letter, however, every letter is read — your time and opinion is greatly appreciated. Letters of particular interest and significance may be published at the Editors discretion. Any correspondence not intended for publication must be clearly marked as such.

TECHNOLOGY WATCH!

with Keith Brindley

Telephone systems are undergoing a small (well, pretty big really) change at the moment. It only needs the examples of many of the large banks' automated telephone banking services to see what I mean. You are given a telephone number to call, a PIN number to identify you, maybe a password (which could be your account number, say) and hey presto, you've got an electronic at-a-distance banking service which lets you check your account balance, pay bills, and maybe order a new cheque book. For the user, operation is quite simple if a little impersonal; an automatic voice message asks you to key in numbers on your telephone's keyset to access the services you want. Alternatively, you may be able to speak to the service if it can recognise voice too. There are many other examples of similar systems – automatic answering services, information desks, service engineer call-out systems and so on – which all use the same technology.

Such systems are only the first in a long line which combine telephones and computers. What we see happening is, in fact, just the beginning. There'll be more to come, as more and more companies see the supposed benefits of automating previously people-intensive services.

In reality, the service is a fairly straightforward combination of computers and telephones, known under various acronyms such as, CTI (computer telephony integration), CIT (computer-integrated telephony), ATS (automated telephone service), and IVR (interactive voice response). Doubtless many more acronyms will emerge as the technology progresses. Whatever the acronym, though, whatever the combination of computer and telephone, they all have a single main function – that of voice processing, where the recorded voice message is actually digitised and stored on computer disk, and where the user's voice is either similarly stored or recognised by the computer as having a specific meaning.

By considering this main function, we can therefore see that there are only three main derivatives of any such system:

1. Automated attendant – in which users are greeted with a voice message. Good examples are speaking clocks, train or bus timetables.
2. Voice mail/messaging – in which users have a personal voice mailbox. This operates just like a standard telephone answering machine does, except that your outgoing message is digitally stored on a computer, as are all incoming messages.
3. Voice or keyed response – in which users can access features within the system by speaking (sometimes) or keying in access numbers. Features vary but several standard types exist: obtaining or leaving voice messages, electronic routeing to departments within the organisation, retrieval of account information, access to leave a sales order, and so on. Indeed your favourite component supplier, Maplin, has such a system, called Keycall, where you can check stock levels and place your order.

Such systems have developed elsewhere in the world far faster than they have in the UK. Indeed, we lag several years behind some countries. This is because of the very low penetration of touch tone telephones here, which are needed to access such systems if they're not capable of voice recognition. To date not many systems have had voice recognition capabilities as this is still a largely flaky computer area – although rapidly improving. Basically, if customers can't access a service there's little point in having the service in the first place. But things are slowly changing, more and more people in the UK are buying touch tone telephones and the current figure (20%) of homes with a touch tone telephone is rapidly getting bigger. Couple this with the rise of better voice recognition capabilities in computers and, as a direct result, we're going to see a big rise in these systems over the next couple of years.

I have very mixed feelings about this. I mean, I like and use telephone banking services, even though the quasi-human automatic messages and responses grate on me. I detest any form of telephone answering machine (even the common household varieties) and would rather leave no message at all than blurting out what I want to say after the tone yet, in the same breath, I positively abhor being put on hold with junk Muzak® to pacify me. In the end, I guess it all boils down to the fact that such services (all such services, of whatever type and ability) are inevitably highly impersonal. While I enjoy using a machine like my computer for what it's worth (an expensive tool, no more no less), I have no desire to treat it as an equal by talking to the damnable thing and worse, it 'talking' back. Don't get me wrong, I'm no Luddite – far from it – there's few who advocate and use technology any more than me. Any regular reader of mine will know that, it's just that I don't get on with electronic appliances quite the way I do with people. Neither do I want to. To me, a tool's a tool; and a person's an individual.

I suspect there are many people like me (indeed, I hope there are many like me) who feel the same way. If so, all these companies who are installing computer-integrated telephone systems with the idea of jumping on the automatic telephone service bandwagon may be about to get a big jolt if the wagon has no springs. It's not known yet how these services' introduction will affect customer satisfaction. It's certainly not known yet how they will affect a company's sales. Maybe they will have an adverse effect on both. Maybe what customers really want is personal service. Keying in numbers to get your bank account details is much removed from grappling with an electronic switchboard when you 'phone for customer help. See that nail? When I nod my head, you hit it with the hammer.

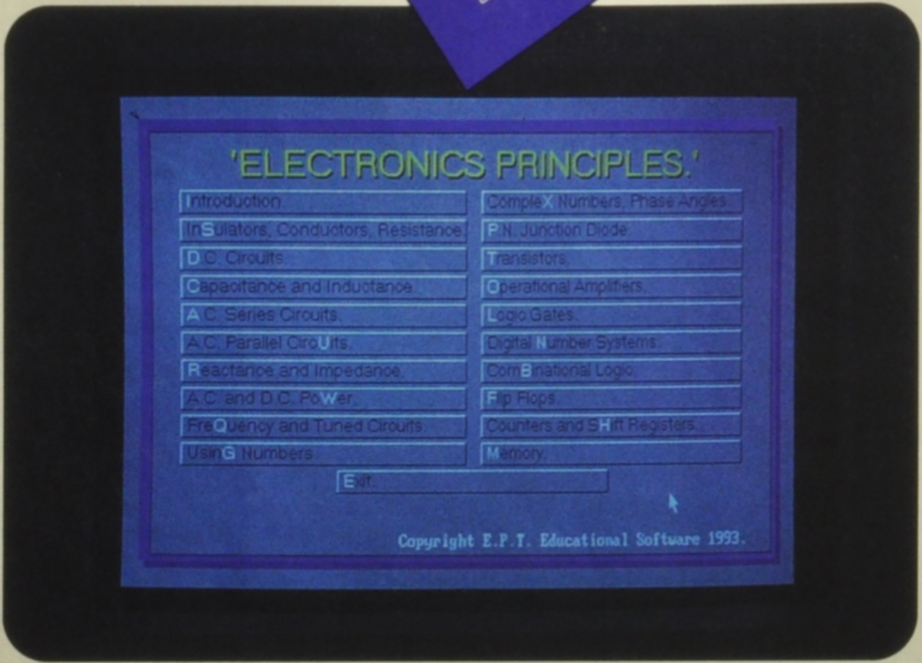
The image of the computer Hal in Arthur C. Clarke's classic 2001 – A Space Odyssey frightens me. Yet, we've only got seven years left so let's not get carried away with this particular field of technology and make the image turn to reality. It's an interesting paradox, but one way of ensuring companies understand that personal services are still wanted by customers, is for customers to write, as well as phone. Maybe, on a point of principle, we should all do it (write, that is!) sometimes. Perhaps Maplin have got the right idea, since they offer both traditional human and automated computer answering systems!

LIFE WITH MICRO CHIP...
"and another thing. I want free banking – 14% Interest on my current account, a dozen of those Fluffy things you give to kids and there's more.
I don't care if you're 7ft tall. You and me are gonna come to blows if I don't get your badge!"
"These voice automated banking facilities are a cinch for giving em' what for and getting away with it!"

IBM PC BASED 'ELECTRONICS PRINCIPLES'

from
E.P.T.
Educational
Software

Reviewed by
J. R. Mosely



Above: 'Electronic Principles' main menu. The software package was conceived and written by Clive Humphris.

Below left: The transistor construction screen, part of the transistor theory topic.

Below right: One of the several interactive screens on AC theory.

THE software is supplied on three 3½in. high density (HD) disks (1·44Mb), and sets out to explain the basic fundamentals of electronics. To run the software you will require an IBM PC or compatible machine with an EGA/VGA graphics card, a hard drive with at least 3·5M bytes of free space and, preferably, a mouse. In addition a colour monitor will be required for best results.

INSTALLATION

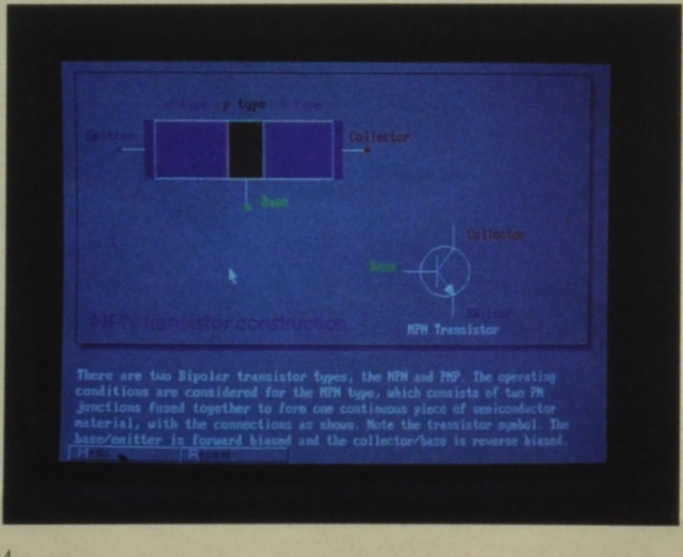
Installation is very simple. Disk 1 is inserted into the appropriate 3½in. drive and 'install' is typed at the relevant drive prompt. Installation is very quick, and when completed the program is ready for use immediately, as no additional setting up is required.

THE PROGRAM

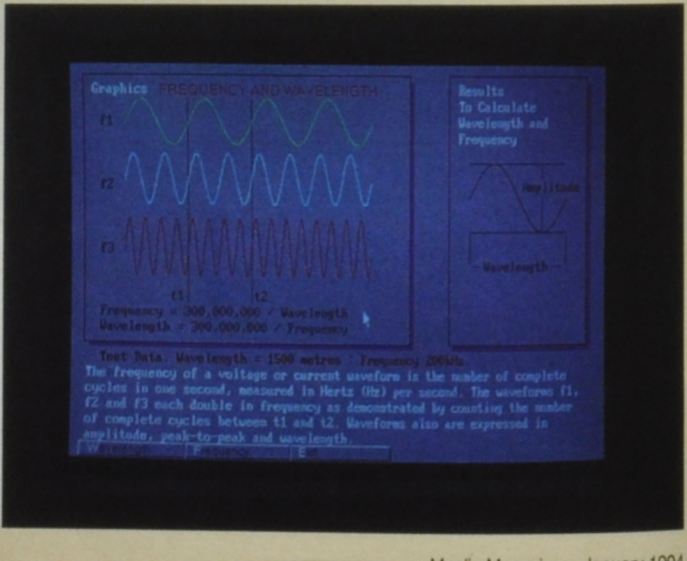
As the opening introductory screen points out, the package is made up of a series of 'programs', having between them over 200 menu driven user screens with fully interactive graphics. This 'learning through doing' approach encourages experimentation. It is possible to exit the introduction screen at any time, and this will take you to the main menu screen.

You can now select one of the 19 'programs' by either pointing and clicking the mouse, or by keying in the highlighted letter in the menu option required. The fact that they are individual programs is, however, transparent, they actually behave like subsections of the main menu. Together the 19 submenus cover subjects as diverse as insulators, conductors and properties of resistance, through AC and DC circuits, frequency related subjects, to diodes and transistors, logic gates and operational amplifiers. The submenu is then further subdivided into an introduction and various topics that cover all aspects of the chosen subject.

As an example, the main menu option 'Frequency and Tuned Circuits' has nine



There are two Bipolar transistor types, the NPN and PNP. The operating conditions are considered for the NPN type, which consists of two PN junctions fused together to form one continuous piece of semiconductor material, with the connections as shown. Note the transistor symbol. The base/emitter is forward biased and the collector/base is reverse biased.



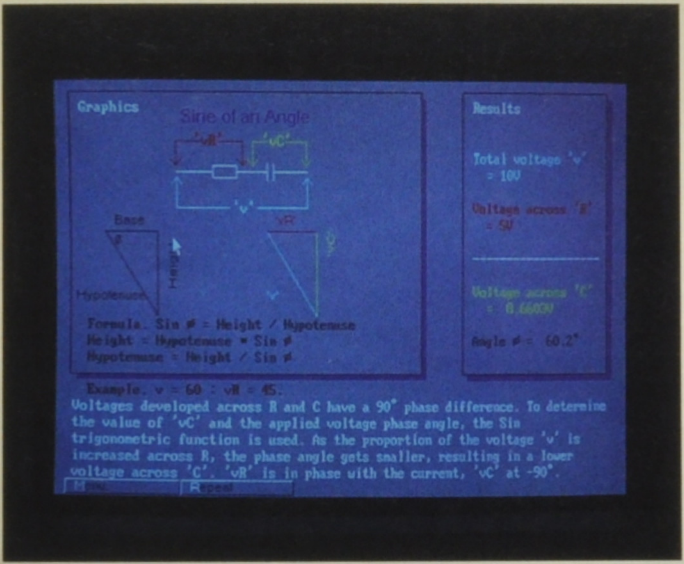
Frequency = 300,000,000 / Wavelength
Wavelength = 300,000,000 / Frequency

Test Data: Wavelength = 1500 metres : Frequency 200kHz

The frequency of a voltage or current waveform is the number of complete cycles in one second, measured in Hertz (Hz) per second. The waveforms f1, f2 and f3 each double in frequency as demonstrated by counting the number of complete cycles between t1 and t2. Waveforms also are expressed in amplitude, peak-to-peak and wavelength.

topics including an introduction. The other eight topics include: Frequency and Wavelength; Resonance; Series Circuit Resonance; Parallel Circuit Resonance; 'Q' of a Tuned Circuit; Tuned Circuit Bandwidth; Coupling Tuned Circuits; Acceptors and Rejectors. Again, the introduction gives a concise and informative overview of the selected topic. In this instance, a topic can be selected by either placing the mouse cursor on it and double-clicking, or clicking once and then clicking on '< OK >' at bottom left, or by using the menu bar. The menu bar is activated by pressing the 'tab' key (normally twice to get the cursor into the menu window), and then using the cursor arrow keys to put the bar on the desired topic, which is then selected by keying 'Enter'.

There may be more options in the list than can be accommodated in the menu window on the screen, in which case it is a simple matter to scroll the bar up or down the list to reveal the other options. This can also be done by clicking with the mouse on the up and down arrow symbols on the right-hand edge of the menu window.



Formula. Sin ø = Height / Hypotenuse
Height = Hypotenuse * Sin ø
Hypotenuse = Height / Sin ø

Total voltage 'v' = 10V

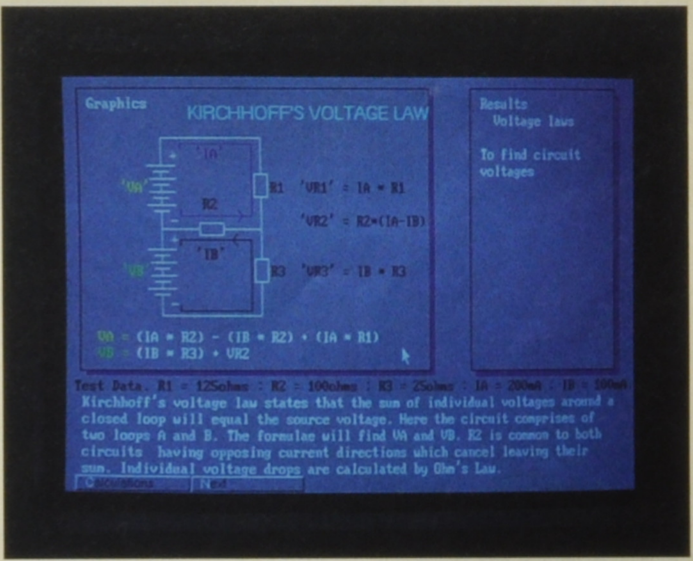
Voltage across 'R' = 5V

Voltage across 'C' = 8.6603V

Angle ø = 60.2°

Example. v = 60 : vR = 45.

Voltages developed across R and C have a 90° phase difference. To determine the value of 'vC' and the applied voltage phase angle, the Sin trigonometric function is used. As the proportion of the voltage 'v' is increased across R, the phase angle gets smaller, resulting in a lower voltage across 'C'. 'vR' is in phase with the current, 'vC' at -90°.



'VR1' = IA * R1

'VR2' = R2*(IA-IB)

'VR3' = IB * R3

VA = (IA * R2) - (IB * R2) + (IA * R1)
VB = (IB * R3) + VR2

Voltage laws

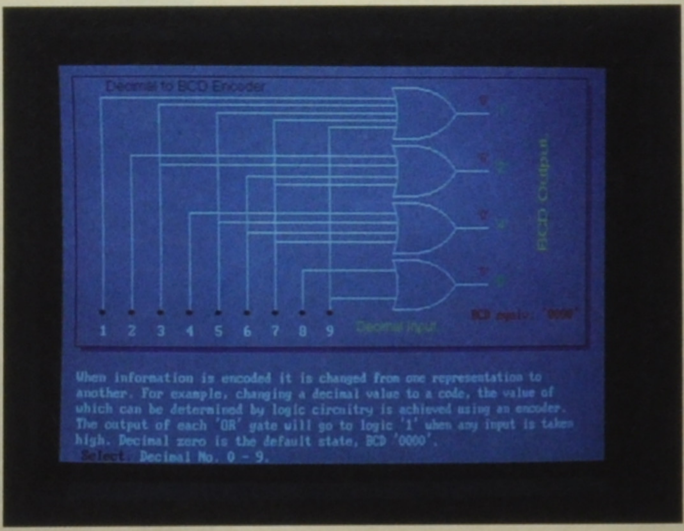
To find circuit voltages

Test Data. R1 = 125ohms : R2 = 100ohms : R3 = 25ohms : IA = 200mA : IB = 100mA

Kirchhoff's voltage law states that the sum of individual voltages around a closed loop will equal the source voltage. Here the circuit comprises of two loops A and B. The formulae will find VA and VB. R2 is common to both circuits having opposing current directions which cancel leaving their sum. Individual voltage drops are calculated by Ohm's Law.

Above: An interactive screen showing current versus voltage vectors in an RC circuit.
Above right: Demonstration of Kirchhoff's law.
Right: An example of a complex logic array. Again it is interactive and you can enter various binary codes which will be converted by the array into BCD while you watch.

The introduction that accompanies the selected submenu gives a brief overview, and is aimed primarily at the beginner and novice. However, it does provide a handy refresher for the more experienced electronics enthusiasts. After you have read the introduction you can then select one of the topics. On selecting a topic it becomes apparent that a colour monitor is desirable, as colour is used extensively to distinguish between different frequency sine waves, for instance.



When information is encoded it is changed from one representation to another. For example, changing a decimal value to a code, the value of which can be determined by logic circuitry is achieved using an encoder. The output of each 'OR' gate will go to logic '1' when any input is taken high. Decimal zero is the default state, BCD '0000'.

Decimal No. 0 - 9.

The topic screen is normally divided into a graphic display area, a results area and the text area (the bottom third of the screen). The descriptive text is concise and informative and is generally more than adequate. In most cases, you are invited to insert your own values, with the results displayed in the relevant box. Values can be inserted in their usual forms, for instance, 1500Ω can be input as 1500, 1k5 or 1·5k. You then have the option to select a screen that will display the actual calculation if you wish, or to repeat the calculation with different values. The experienced electronics engineer and/or designer may well find this facility useful for calculating circuit parameters for their own designs.

The package is very easy to use and will provide the student, or novice, with a more enjoyable alternative to a 'bland' text book. It certainly makes learning Electronics a lot more interesting! Graphical representation is extremely good with waveforms being produced particularly well. The various photographs show the range of useful topics, from resistor colour codes to sine wave analysis. Students will find the ability to check calculations a very useful feature.

CONCLUSION

The package would be ideal for schools and colleges that are offering Electronics or related courses at various levels and a small work book, written by Mike Tooley, accompanies the package. The package costs £49.95 plus £2.00 post and packing, and can be obtained by directly contacting E.P.T. Educational Software, 'Pump House', Lockram Lane, Witham, Essex CM8 2BJ, Tel: (0376) 514008. A demonstration disk is also available for £2.00.

A further useful utility, 'Electronics PC Toolbox', is also available which comprises over 100 commonly used formulae and routines. It operates in a manner identical to the 'Principles' package and is also supplied on a $3^1/_2$in. HD disk. Again installation onto a hard drive is possible if desired, or the utility can be run from the floppy. To use, a formula is selected from the menus, the desired values keyed in and the results are instantly displayed. The 'Toolbox' can be obtained from E.P.T. Educational Software at the above address, price £14.95 plus £1.00 post and packing.

NEWS Report

PCMCIA Drive

As the computer industry standardises on the PCMCIA interface for removable peripherals, disk drive manufacturers are battling to develop the drive with the largest capacity.

Maxtor claim to be leading the way with the MXL-105-III, a 105MB, 1·8in., drive that is more than double the capacity of other PCMCIA drives.

The size of a credit card and weighing just 2·5 ounces, the removable drive is designed for use in notebook, portable and desktop computers.

Since removable data is the preferred storage solution for applications requiring data security, the MXL-105-III features a patented security system with password protection to prevent unauthorised users from accessing data.

Intelligent power management features keep power consumption to a minimum. Less than 2W are used in the drive's read/write mode, decreasing to 0·025W in standby mode. Contact: Maxtor (071) 831 4890.

Payphone Protection

BT is to begin trials of a unique alarm system to help protect its payphone theft attacks costing millions of pounds.

Telephone kiosks are to be monitored by audio and visual alarm technology provided by Modern Securities Limited. The alarms can actually see and hear attempts to break into cash compartments and send pictures or real-time audio confirmation over the telephone line to Modern's 24-hour central monitoring station.

"Confirmation of the occurrence of a crime is essential to the projects success", explains Mr. Adrian Casey, national accounts general manager of Modern Security Systems. "It allows us to notify police of an offence in progress with a high degree of reliability."

Trials are to begin shortly at 50 test sites. Preliminary tests at a small number of selected payphones have already shown encouraging results. In two incidents, verified alarm signals forced offenders to flee abandoning tools they were using to try to attack cash compartments.

WordPerfect – The Next Generation

The WordPerfect Corporation is about to launch WordPerfect 6.0 for Windows, the next version of its Windows-based word processor. The package will offer complete customisation enabling users of the DOS version to make the transition to the Windows environment.

"We have completely rewritten all of the WordPerfect software to give users the best in Windows word processing", says Mr. Alan Ashton, president of the WordPerfect Corporation. "Virtually every feature of the product has been improved or enhanced in some way as a result of thousands of user requests, feedback from focus groups and extensive usability testing."

WordPerfect 6.0 will require a 386 machine or higher and at least 4MB. The complete package will retail at £329. Contact: WordPerfect (0932) 850505.

£80m Wind Farm for Northumberland

An £80 million wind farm, approved in principle by Northumberland County Council and the Countryside Commission, is now awaiting consent from energy minister Mr. Tim Eggar.

Claimed to be the largest wind generation project outside California, the wind farm is expected to be built next year at Kielder Forest, Northumberland, eight miles from Hadrian's Wall. The consensus of the countryside commission now makes government approval likely, which means that the wind farm could start generating by 1995.

The farm will consist of between 160 and 267 wind turbines up to 170ft high depending on the energy capability of individual devices. Developers estimate the farm would feed up to 80MW of electricity into the electrical grid – enough electricity for 48,000 domestic homes or equivalent to half of Northumberland's needs.

Satellite Data

Fans of Martin Pipe's regular satellite jottings may be interested to hear about the latest edition of the *Satellite Channel Report*.

Containing information gathered from tracking stations around the world, the new A4 volume covers alignment data, video and audio channel information, frequency and encryption methods for satellites across Europe, Africa and the Middle East.

The comprehensive guide is compiled and updated monthly ensuring readers obtain the latest available information. This compares favourably with other satellite magazines where preparation lead times can be up to three months meaning information is often out of date before it reaches its readers.

The 80 page report compiled by Mr. W. T. Smith, costs £15.00 and is available exclusively from Swift Television Publications. Contact: Swift Television Publications (0793) 750620.

Seeing Double

Developed by Datapath, TWINdows is a dual screen driver for use with the Microsoft Windows based PC platform. It is essentially a hardware solution that will allow multiple graphics cards to run simultaneously in the same machine doubling Windows workspace across multiple screens.

Capable of driving two 1280 by 1024 pixel screens, TWINdows allows two applications to be viewed full size simultaneously. This enables an operator to use a word processor on one screen for example, and a spreadsheet or graphics package on another. Using TWINdows, images from one package can be transferred to the other without minimising either application. Contact: Datapath (0332) 294441.

Mobile Warning

Telephone users be warned, Vodaphone has reduced the time allowed for a call to and from a mobile phone to be deemed successful from four to two seconds. Customers should be vigilant and check their itemised bills for these sub-five second calls.

A complaint directed towards Vodaphone would seem appropriate, but expect the reply we received, ". . . other mobile phone operators do not offer any connection period before charging commences". True, but in the light of Vodaphone's recent charge reductions to meet improved competition it seems just a little tight-fisted.

Mountain Fax Back

A Lake District mountain rescue team have made a valuable technological addition to their life-saving equipment. The Langdale and Ambleside crew now pack a mobile fax machine in their kit whenever they are called out to a fell-side accident.

The 40 members of the team who are all medically trained, also take heart and respiratory monitoring equipment that can provide precise details of an accident victim's condition within seconds. Readings are then sent via fax to a hospital in Barrow in Furness where a consultant can study information and relay back advice on treatment.

The machine has already proved its worth. A woman who suffered a heart attack 2,000ft up Langdale Fell was treated on the spot, under the direction of a hospital-based consultant.

Tiny Data Logger

Orion Components of Chichester have launched Tinytalk, a miniature, low-cost, self-contained data logger.

The first model in the range is the Tinytalk-Temp, a temperature logging version that will log local temperatures in virtually any situation – in a washing machine, in a freezer lorry or a humidity oven.

The self-contained data logger will fit inside a splashproof case the size of a 35mm film canister and weighs just 28g. The –39°C to +123°C has the widest range and a resolution of 0·16°C at 15°C and is optimised for water monitoring, while the –37°C to +46°C version has a resolution of 0·26°C at 0°C suitable for perishable products and shipping temperatures.

Its non-volatile memory stores 1800 readings that can be taken at intervals between 0·5 seconds and 4·8 hours giving logging durations of 15 minutes to a day respectively.

Tinytalk data loggers are launched, interrogated and data plotted using host software on a PC. A launch dialogue box, allows selection of the sample duration and entry of a text block used to describe data. There is also the choice of what to do when the memory is full – either stop recording the data, or overwrite existing data.

Off-loaded data is immediately displayed as a graphical plot. Sections of the plot can then be expanded to give greater resolution, any of these plots can then be sent to a printer. The host software can also produce spreadsheet output in both Excel and Lotus 1-2-3 formats. Contact: Orion Components (0243) 778088.

Maplin Empire Expands

The number of Maplin shops increases by four, located at Northampton, Milton Keynes, Stockport, and Cheetham Hill in Manchester. The new Stockport and Manchester shops are already open, while the Northampton shop is due to open on the 29th November 1993, and Milton Keynes on 6th December 1993.

Addresses are: Northampton Shop: 139 St. James Road, Northampton, NN5 5LE, Tel: (0604) 756726. Milton Keynes: Office World Building, Unit 1, Grampian Gate, Winter Hill, Milton Keynes, MK6 1BD, Tel: (0908) 692720. Stockport: 259-261 Wellington Road South, Stockport, SK2 6ND, Tel: (061) 480 4900. Cheetham Hill: 169 Cheetham Hill Road, Cheetham Hill, Manchester, M8 8LG, Tel: (061) 832 2550.

650MB CD for Multimedia Applications

Memory technology this month announced the launch of CD Shuttle, a portable CD ROM drive, that provides customers with cost-effective multi-media capability. The new drive joins the Shuttle range of portable peripheral storage devices that include DAT and magnetic-optic products.

The 650MB read-only drive has two data transmission speeds – 150K-Bytes/s and 300K-Bytes/s – and attaches to any PC port interface or host adaptor. Other features include Kodak Photo CD and multi-function XA support as well as full multimedia compatibility.

"Not only is multimedia taking off rapidly, but the market is experiencing considerable growth in software house, distributing operating systems, applications and reference material on CD ROM. The CD Shuttle offers a simple means of utilising this technology on existing systems in the office or on remote PCs without large-scale hardware upgrading", says Mr. Alan Jones, Managing Director of Memory Technology. Contact: Memory Technology (071) 831 4890.

Young Woman Carries Off Top Engineering Award

A 16-year old woman has carried off the title of 'Young Engineer for Britain 1993'. It is the second year running that a young woman has won the distinguished award.

Lucy Porter, of Bath, won the coveted trophy, a £500 personal prize and £1,500 for the purchase of engineering equipment by her school. She also carried off The Engineering Council's Woman Into Science and Engineering (WISE) award of £500 for the best project by a young woman.

Lucy won the awards by inventing a leg swing exerciser for children with special needs, who are not able to use their legs. She plans to be an engineer and after winning the award said, "Engineering is really addictive. It is so satisfying to design and make something which can solve a problem."

Lucy was one of 53 national finalists, aged 15 to 19, competing in the national final of the competition organised by the Engineering Council. They had been selected at 12 regional events from a record 970 young people who had competed for prizes totalling £20,000.

Presenting the awards, The Lord Mayor of London, Sir Francis McWilliams, FEng, said, "It is highly appropriate that the final of the Young Engineers for Britain competition is taking place in the city of London, one of the oldest and most important business centres of the world.

"That fact should serve to remind us that the worlds of engineering and commerce, often portrayed as remote from each other, are in fact inextricably linked. Quite simply trade, banking, insurance and all the various business operations carried out in the City of London ultimately depend upon and derive their justification from the manufacturing and construction industries."

Top Flight Awards

Nearly 3,500 schools and further education colleges throughout the UK will shortly be receiving details of a new initiative to encourage high-achieving students into accredited engineering degree courses.

The Top Flight bursary scheme will provide suitably qualified students with £500 per year in addition to their maintenance grants for the duration of their undergraduate courses.

Students embarking on engineering degree courses in the Autumn of 1994, 1995 and 1996 will be eligible to apply for the bursary providing they have A-level grades of AAB or equivalent.

Altogether £10 million of funds has been provided by the Department of Education for this scheme, which will be administered by the Engineering Council.

Commenting on the bursary awards, Mr. Tim Boswell, Parliamentary Under-Secretary of State for Education, said, "By seeking to encourage high calibre students into engineering this scheme will raise awareness of the value of engineering and ultimately help British industry compete more successfully in world markets."

Up to 2,000 students a year are expected to qualify for the bursaries and applications will be accepted from students attending both sandwich, part-time and full-time courses.

If you think that you might qualify for a bursary contact your school or college headteacher who should have details of the scheme. Alternatively call the Engineering Council for more information. Contact: The Engineering Council (071) 240 7891.

Ergonomic Mouse

One of the main aims of both hardware and software producers when they are planning and developing new products is to fulfil the users perceived requirements, but in pursuing these ends the insignificant often gets overlooked.

For example, we only have to look no further than the computer desk top. It now seems after many successful years of use that the layout of the keys on a keyboard can be used more efficiently if they are rearranged. We also have the crazy situation where the brand of a mouse is often more popular than its design.

Insignificant? Well no, both keyboard and mouse have been criticised of late as causes of the crippling condition, repetitive strain injury (RSI).

Assman Electronics revolutionary concepts for their new mouse were derived from ergonomic studies. These were then used to determine not only the very different shape but also the way in which the mouse functions. These ideas are now combined in a single unit, a mouse called Digitus which you use with your thumb – only used until recently to manoeuvre the mouse.

The design of Digitus cradles the hand in a natural resting position, allowing the user to operate the mouse for long periods without experiencing the tiredness and cramp that often accompany inferior products.

The two button mouse is compatible with Microsoft, Mouse Systems, IBM and PS2. It works accurately with all DOS systems higher than version 3.00 and is priced at £32.90. Contact: Watford Electronics (0923) 244398.

BBC Commences DAB Trials

The BBC has begun engineering tests of Digital Audio Broadcasting (DAB) using high-power transmitters in the London area, to enable research to be carried out on the coverage aspects of DAB.

Currently one 10kW transmitter at Crystal Palace is in operation, together with three other 1kW devices at Alexandra Palace, Reigate and Wrotham. The transmitters will be operating on the same VHF frequency – 226MHz, and have been borrowed from the Harris Corporation for the duration of the tests.

Specially equipped survey vehicles will be measuring the field strength of the individual transmitters and the way in which they work together to form a single frequency network. It is anticipated that in the UK a number of national and local DAB services will broadcast terrestrially using DAB frequencies. Following the completion of the test the BBC expects to produce detailed proposals for the introduction of DAB throughout the UK.

DAB is an entirely new radio broadcasting system, that will offer reliable reception with high quality sound, to a new generation of mobile, static and portable radio receivers. The system has been tested throughout Europe to widespread acclaim, having been first demonstrated publicly in the UK at the Radio Festival, Birmingham, in July 1991.

The BBC is the sole UK member of the Eureka 147 Project which is developing the DAB system. The consortium includes broadcasters, research establishments and receiver manufacturers thus ensuring all aspects of development are covered.

Speaking Science

Earlier this month Professor Stephen Hawkings opened the Science Museum exhibition Speak to Me. The exhibition, sponsored by Nuclear Electric plc, explores the role of new technologies in improving communication for people with disabilities. As a sufferer or motor neurone disease – a rare wasting condition of the nervous system – Professor Hawking's only means of communication is via a speech synthesizer operated by two fingers of his left hand.

Special features of the exhibition include: the speech synthesizer 'Liberator' which uses pictures instead of letters; a speaking hand that translates the Deafblind Alphabet into synthesized speech; and holograms which demonstrate British Sign Language.

The exhibition is part of the Science box series of exhibitions on contemporary science and technology and is open to the public until January 1994.

Opening Times: 10.00am to 6.00pm Monday to Saturday, 11.00am to 6.00pm Sunday. *Cost:* Adults £4.00, Children and Concessions £2.10. *Time Required:* A full day to see all exhibitions.

Left in the Dark

Occasionally an innovative product is launched, with a concept so simple that engineers, designers and technicians are left wondering how they ever let the idea slip by. This month Orion Electronics will leave many deep in thought.

Troubled with visitors trying to locate their building in the dark, the company has launched Numberlite. By day 4in. black digits on a white background identify the building, while at night the numbers automatically light up in bright red.

The patented system is modular, so any number can be made up from individual digits. Numberlite operates from a 24V supply, powered from 240V mains. Contact: Orion Electronics International Ltd. (081) 650 1126.

DIARY DATES

Every possible effort has been made to ensure that the information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments please contact event organisers to confirm details.

Until 30 January. Speak to Me. Exhibition exploring the role technology might have in improving communications for people with disabilities. Science Museum, Exhibition Road, London. Tel: (081) 938 8000.

7 to 8 December. World Telecommunications Conference, Financial Times Conference Organisation, London. Tel: (071) 251 9321.

8 December onwards. Handle with Care First public access to the restored 1830 railway warehouse, Museum of Science and Industry, Manchester. Tel: (061) 832 2244.

11 December. Children's all-night camp-in at Science Museum, Science Museum, Exhibition Road, London. Tel: (081) 938 9785.

13 to 15 December. 7th IEE European Mobile Personal Communications Conference, The Brighton Centre, Brighton. Tel: (071) 240 1871.

18 December. Crystal Palace & District, Radio Club Christmas Social, Video/Film Show at 7.30pm, All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London SE19. Tel: (081) 699 5732.

22 December. Wirral and District Amateur Radio Club, Chairmans Night, Chairmans Surprise Talk at 8.00pm at Irby Cricket Club, Irby, Wirral. Tel: (051) 648 5892.

1 to 8 January. Model Engineer & Modelling Exhibition, Olympia Grand Hall, London. Tel: (0442) 66651.

12 to 15 January. BETT – '94 British Education, Training & Technology, Olympia National Hall, London. Tel: (071) 404 4844.

15 January. Crystal Palace & District Radio Club, QRP (Low Power) Home built Radio Equipment by Wayne Dillon, 7.30pm, All Saints Parish Church Rooms, Beulah Hill, Upper Norwood, London SE19. Tel: (081) 699 5732.

26 January. Wirral and District Amateur Radio Club, Surplus Equipment and Junk Sale at 8.00pm at Irby Cricket Club, Irby, Wirral. Tel: (051) 648 5892.

26 to 27 January. Virtual Reality '94, Olympia 2, London. Tel: (071) 931 9985.

29 January to 2 February. British International Toy & Hobby Fair, Earls Court 2. Tel: (071) 701 7127.

30 January to 2 February. European Lightshow, Earls Court, London. Tel: (0952) 290905.

Please send details of events for inclusion in 'Diary Dates' to: The Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex SS6 8LR.

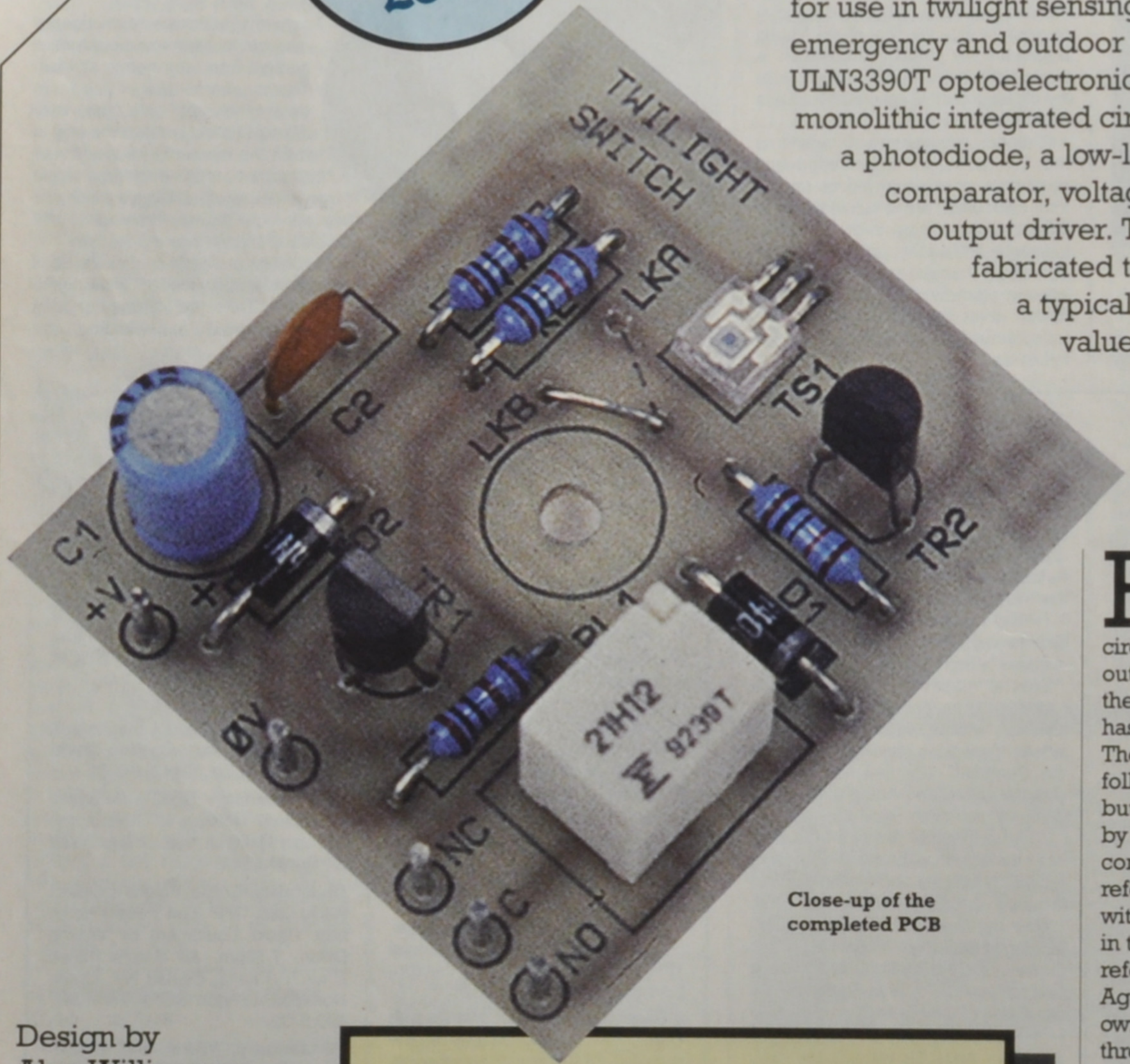
'Data Files' are intended as 'building blocks' for constructors to experiment with and the components suggested, provide a good starting point for futher development.

1
PROJECT
RATING

ULN3390T Twilight Switch

KIT
AVAILABLE
(LT47B)
PRICE
£5.95

This useful module owes its small size and simple construction to the use of a specialised optoelectronic IC. Designed for use in twilight sensing applications, emergency and outdoor lighting, the ULN3390T optoelectronic switch is a 3-pin, monolithic integrated circuit containing a photodiode, a low-level amplifier, comparator, voltage regulator and output driver. The comparator is fabricated to give the sensor a typical built-in hysteresis value of 50%.



Close-up of the completed PCB

Design by
Alan Williamson

Text by
Alan Williamson
and Mike Holmes

FEATURES

- ∗ 50% hysteresis
- ∗ Temperature compensation
- ∗ Photodiode with all on-chip electronics

APPLICATIONS

- ∗ Night-time security
- ∗ Automatic porch light
- ∗ Light/dark sensor

FIGURE 1 shows a simplified block diagram of the internal circuit, together with the pin-outs of the device. Note that the photodiode preamplifier has its own supply regulator. The hysteresis action in the following stage is simply but effectively achieved by having a conventional comparator alter its own reference voltage level with a transistor switch in the bottom end of the reference divider chain. Again this stage has its own regulator, making the threshold points independent of supply voltage level.

With its temperature-compensated, threshold trip points, protection against damage by bright light and increased hysteresis values, the device represents a significant design improvement over previous optoelectronic switches. The sensor is completely integrated with supporting electronics. This maintains stability throughout its

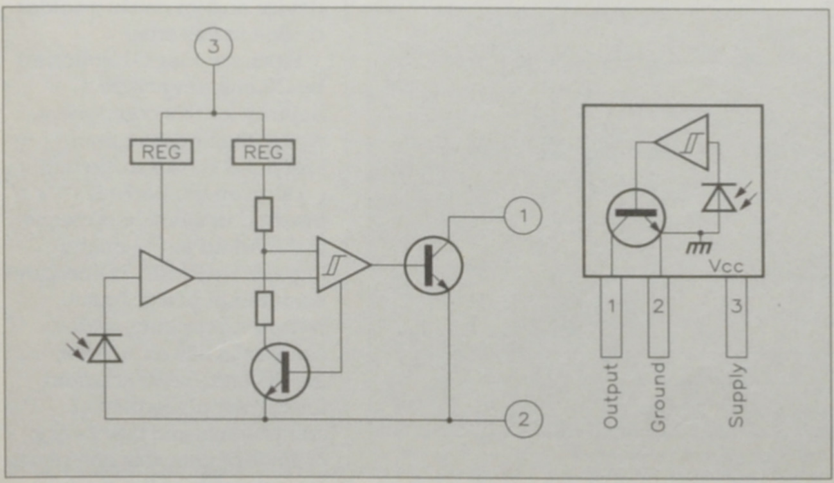


Figure 1. Functional block diagram of ULN3390T and pin out.

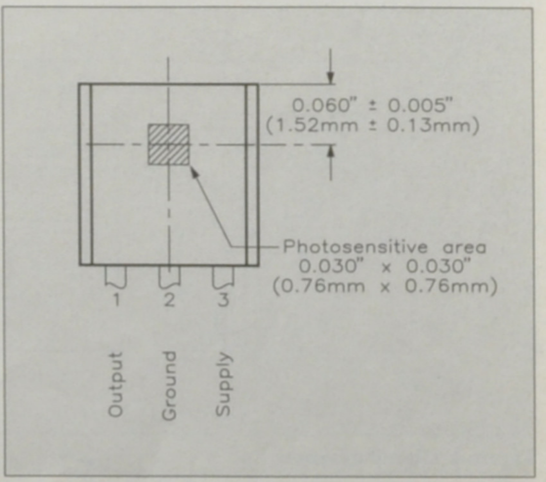


Figure 2. Sensor-centre location.

working life plus immunity to temperature variations compared with cadmium sulphide cell assemblies, requires very few external components and has calibrated switching characteristics.

Figure 2 indicates the position of the photosensitive area in relation to the body of the device. A graph of the spectral response of the photodiode is shown in Figure 3. The ULN3390T switch typically turns on as illumination falls below a level of 10µW/cm² (at a wavelength of 880nm). The internal hysteresis then prevents deactivation until illumination exceeds the 20µWcm² level. Table 1 shows the essential electrical characteristics for the device, where output saturation voltage and leakage current refers to the open collector output switch. Also, while the IC is limited to a supply voltage of 16V maximum, the output switching transistor is rated higher, as shown in Table 2.

Circuit Description

The essential circuit diagram of the Twilight Switch module is shown in Figure 4. Thanks to the ULN3390T IC, the circuit is very simple and mainly consists of the extra power supply and output components in addition to the IC.

To make the module as simple to use as possible, the output switching is performed by a relay, RL1. This provides normally open, normally closed or changeover functions and allows total electrical isolation between the sensor circuit and the controlled circuit. The ULN3390T is quite capable of driving the relay directly but, in order to increase flexibility, two extra transistor stages are included to allow inverted or non-inverted operation of the relay, depending on the position of link LK1.

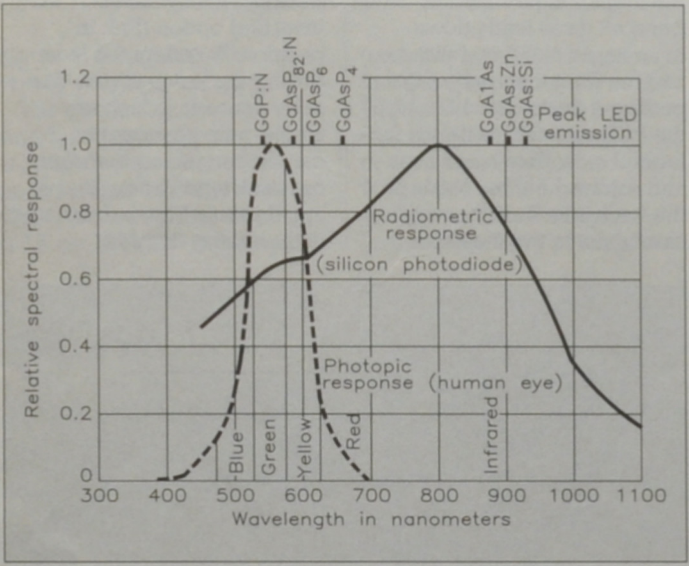


Figure 3. Spectral response as a function of wavelength of light.

	Symbol	Value
Supply voltage:	V_{CC}	25V
Output voltage:	V_{OUT}	25V
Output current:	I_{OUT}	25mA
Operating temperature range:	T_A	–40°C to +85°C

Table 2. Absolute maximum ratings of output transistor.

Characteristic	Symbol	Test conditions	Limits Min	 Typ	 Max	 Units
Supply voltage range:	V_{CC}	Operating	4·0	–	16	V
Supply current:	I_{CC}	$E > E_{OFF}$	–	3·0	10	mA
Output saturation voltage:	$V_{OUT(sat)}$	$I_{OUT} = 15mA$, $E \leq 6\mu W/cm^2$	–	300	500	mV
Output leakage current:	I_{OUT}	$V_{OUT} = 15mV$, $E > E_{OFF}$	–	0·1	10	µA
Output rise time:	t_r	10% to 90%	–	200	500	ns
Output fall time:	t_f	90% to 10%	–	200	500	ns
Light threshold level:	E_{ON}	$\lambda = 880nm$	6·0	10	14	µW/cm²
	E_{OFF}	$\lambda = 880nm$	–	20	–	µW/cm²
Hysteresis:	ΔE	$(E_{OFF}–E_{ON})/E_{OFF}$	45	50	65	%

Table 1. Electrical characteristics @ T_A= +25°C, V_{cc} = 6V.

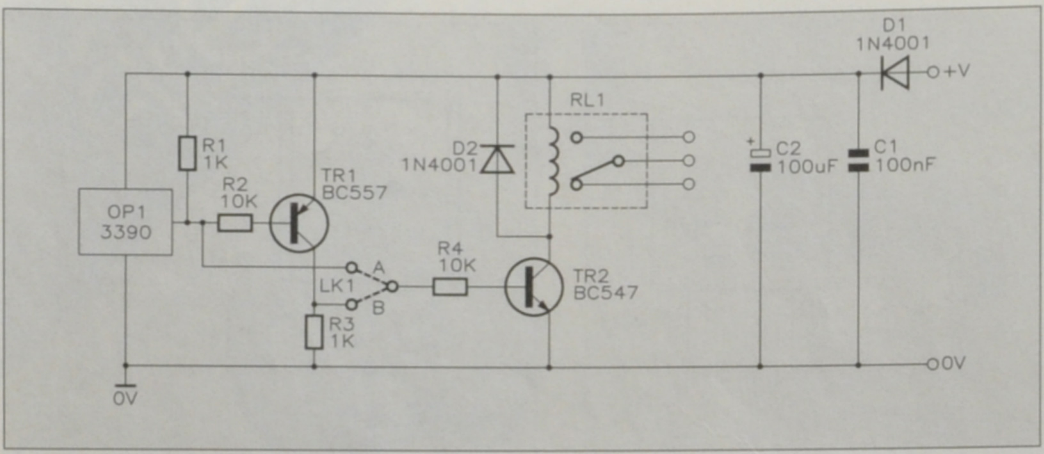


Figure 4. Circuit diagram.

The power supply rail has a reverse blocking diode D1 to protect the circuit against any accidental reversed supply connection, followed by decoupling capacitors C1 & C2. Protection diode D2 is placed across the relay coil to protect TR2 from induced EMF transients on switch-off. The whole circuit is accommodated on a tiny PCB measuring only 41 x 38mm.

Construction

Firstly, with reference to Figure 5, at this stage, insert and solder the five PCB pins followed by resistors R1 & R4. Then you must choose which operating mode is required and fit the wire link, using one of the resistor offcuts. To energise RL1 on the 'light to dark' transition (relay active while dark), all components are required and the wire link is fitted in position 'B'. This option will offer the lowest power consumption in the OFF (light) state. For applications which need to activate the relay on a 'dark to light' transition, TR1, R2 & R3 are not required and can be omitted, the link being fitted in position 'A'. This results in very similar supply current drains for both ON (light) and OFF (dark) states. (Figure 7 shows the differences between the two options in more detail.)

Fit and solder diodes D1 & D2, noting that the silver band at one end of the black body of each diode must correspond to the white stripe on the legend. You can then fit R2, R4 & TR1 if required, followed by TR2. To fit the Twilight Switch IC, OP1, first identify the top surface (with the help of Figure 2), and bend all three leads down to an angle of 90° at a distance of 3mm from the edge of the package. Insert these through the PCB until OP1 is flat on the legend side, then bend over and solder the three leads on the trackside. Be extremely careful not to overheat the device and/or cause a solder bridge in this area!

Fit and solder C1, followed by C2 ensuring correct polarity for this component, where the negative lead, identified by the stripe and (–) sign on the body, is inserted in the hole opposite that marked as (+) on the legend. Lastly RL1 is fitted and soldered in place. Again beware of creating solder bridges in this area. After the PCB has been checked for correct placement of components and the quality of solder joints, this completes the assembly of the module.

Input	Action (RL1)	Link (LK1)	Supply current
Light to dark:	ON	B	43·8mA @ 12V
	OFF	A	15·9mA @ 12V
Dark to light:	ON	A	21·4mA @ 12V
	OFF	B	5·3mA @ 12V

Table 3. Specification of prototype.

In Use

Table 3 indicates the typical current consumption of the module in the two different modes of operation for the two states. If it is intended to be battery powered then the inverting option (link in position 'A') offers the least power drain during the dark period, while the non-inverting option (link in position 'B') offers the least during the light period. The relay contacts, which are single-pole changeover, can be connected to make or break when energised as appropriate. This is illustrated in the wiring diagram

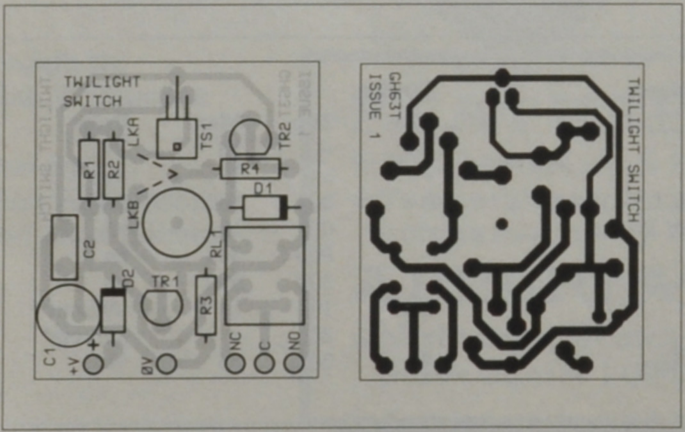


Figure 5. PCB legend and track.

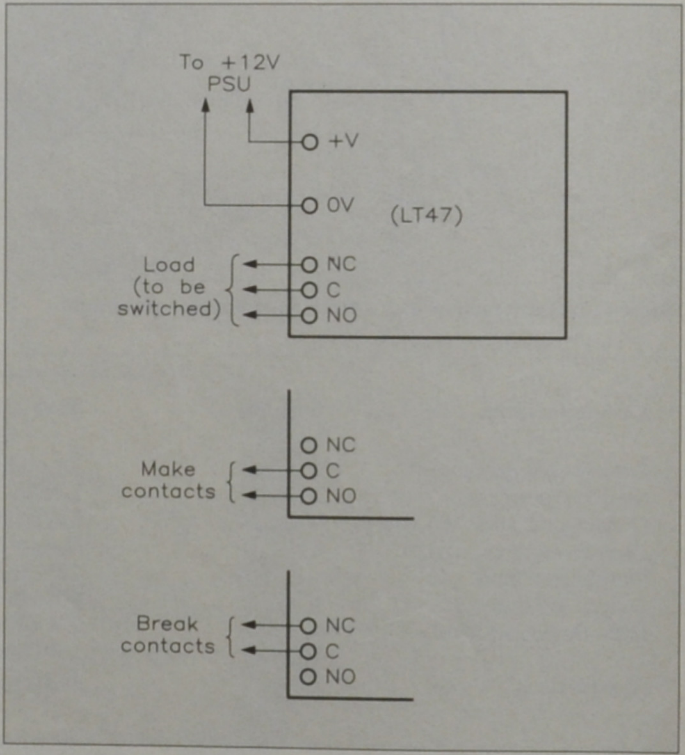


Figure 6. Wiring diagram.

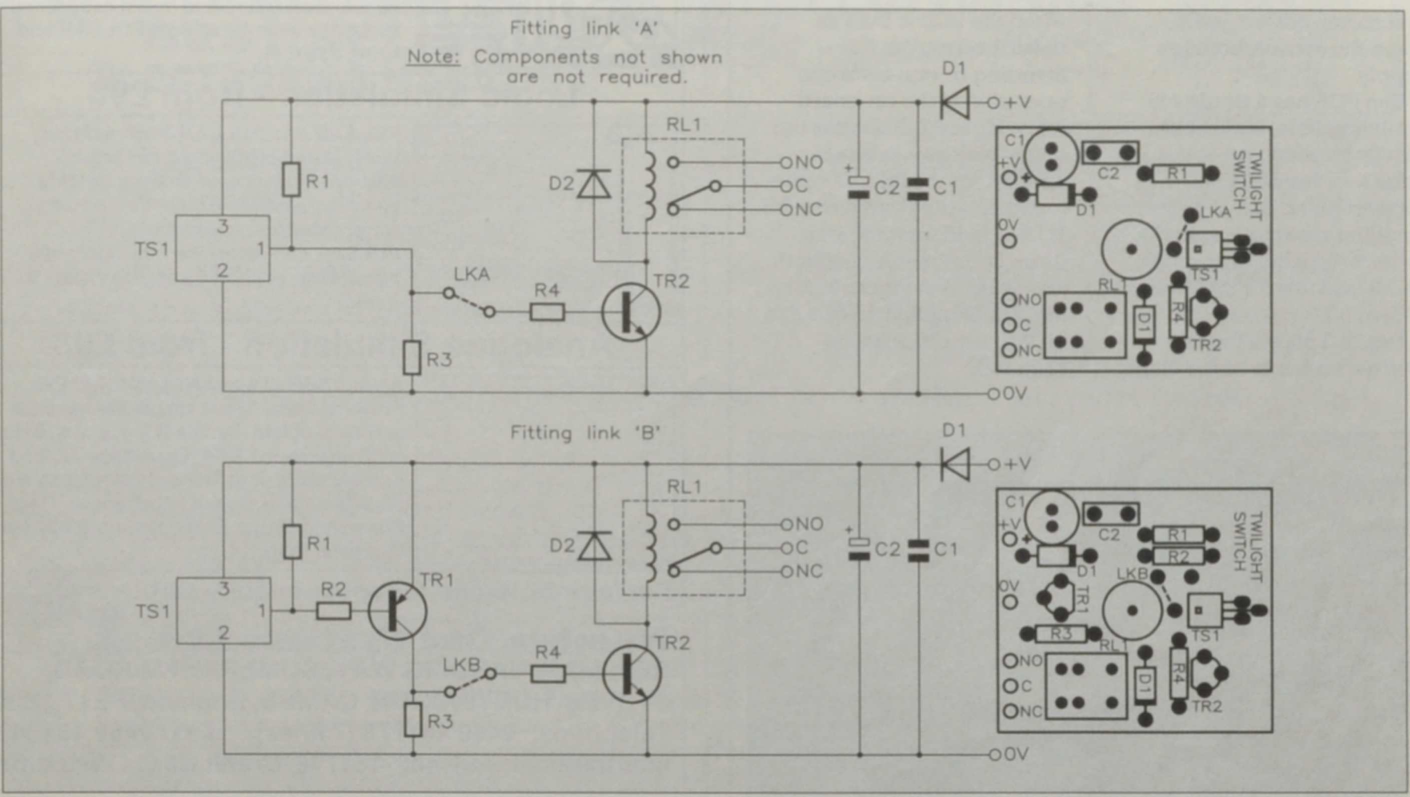
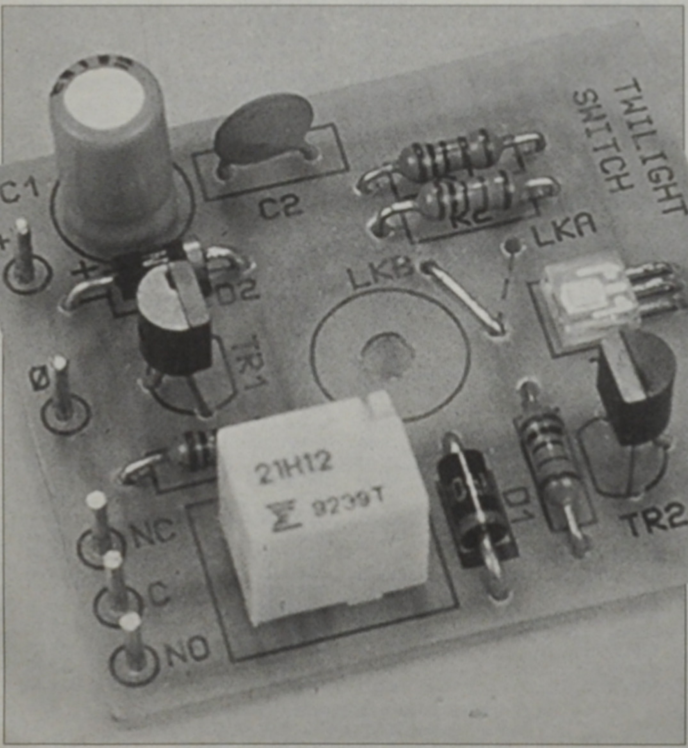


Figure 7. Circuits and component legends for the two build options.

Figure 6, along with the supply connections.

The circuit requires a supply of nominally 12V DC at 50mA maximum, but can be as high as 16V. The relay is capable of switching 28V DC at 1A, or 120V AC at 500mA (resistive load only), except that the close proximity of the PCB tracks only allow a safe maximum voltage at the contact connections of 50V, which should not be exceeded. This arrangement is, therefore, NOT suitable for mains use! If you wish to control mains powered devices then the on-board relay should be used as a 'master' to operate a higher power mains rated relay, such as Order Code YX97F. This is a SPCO ultra-miniature relay capable of switching resistive loads up to 10A at 240V AC, suitable for lighting or appliances up to 2kW (3A max. for inductive loads). It is a PCB mounted type and has a 12V coil with a low current consumption of 37mA,



The completed Twilight Sensor PCB.

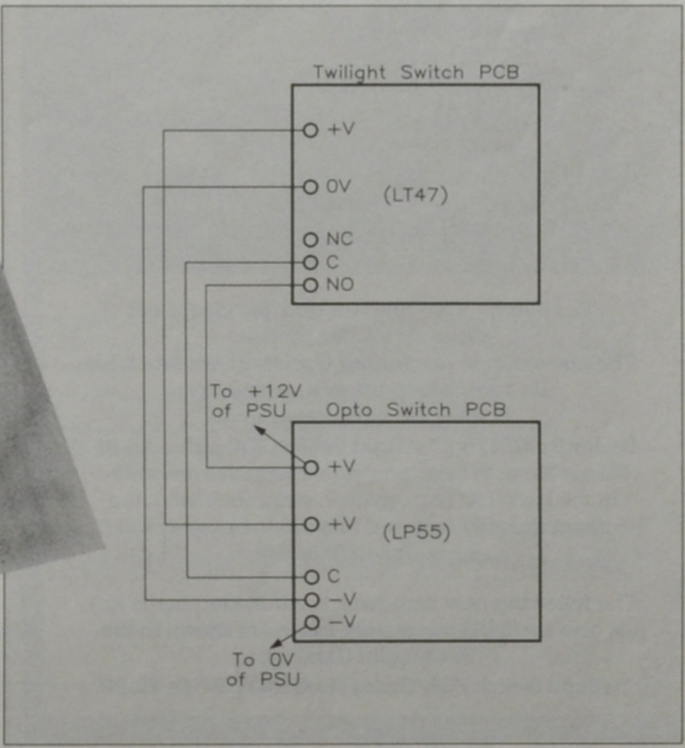


Figure 8. Connecting Zero-Crossing opto-switch.

and so can conveniently share the sensor module's supply.

The PCB has a single M3 mounting hole, and should ideally be mounted at this point to a threaded M3 support pillar. In this way it could be mounted behind a protective panel or in a box with a window for the Twilight Sensor IC.

Figure 7 shows the two alternative forms of the circuit when the PCB is built as described earlier for inverting or non-inverting operation of the on-board relay. Figure 7 illustrates the circuit with components omitted for the link 'A' option, together with a version of the PCB legend showing only those components required. The version in Figure 7, for the link 'B' option, shows that all the components are required.

TWILIGHT SWITCH PARTS LIST

RESISTORS: All 0·6W 1% Metal Film			
R1,3	1k	2	(M1K)
R2,4	10k	2	(M10K)
CAPACITORS			
C1	100µF 25V Radial Electrolytic	1	(FF11M)
C2	100nF 50V Disc Ceramic	1	(BX03D)
SEMICONDUCTORS			
D1,2	1N4001	2	(QL73Q)
TS1	ULN3390T	1	(CP94C)
TR1	BC557	1	(QQ16S)
TR2	BC547	1	(QQ14Q)
MISCELLANEOUS			
RL1	Micro Min Low Power Relay	1	(DC52G)
	1mm PCB Pins	1 Pkt	(FL24B)
	PCB	1	(GH63T)
	Instruction Leaflet	1	(XU47B)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
	20mm Single Pattress	1	(YB14Q)
	Blanking Plate	1	(HL86T)
	Insulated Spacer M3	1 Pkt	(FS36P)
	AC Adaptor Unregulated 300mA	1	(XX09K)
	2·5mm Panel Mount Power Socket	1	(JK10L)

The Maplin 'Get-You-Working' Service is not available for this project.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT47B (Twilight Switch Kit) Price £5.95.

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately, but is not shown in the 1994 Maplin Catalogue.

Twilight Switch PCB **Order As GH63T Price £2.20.**

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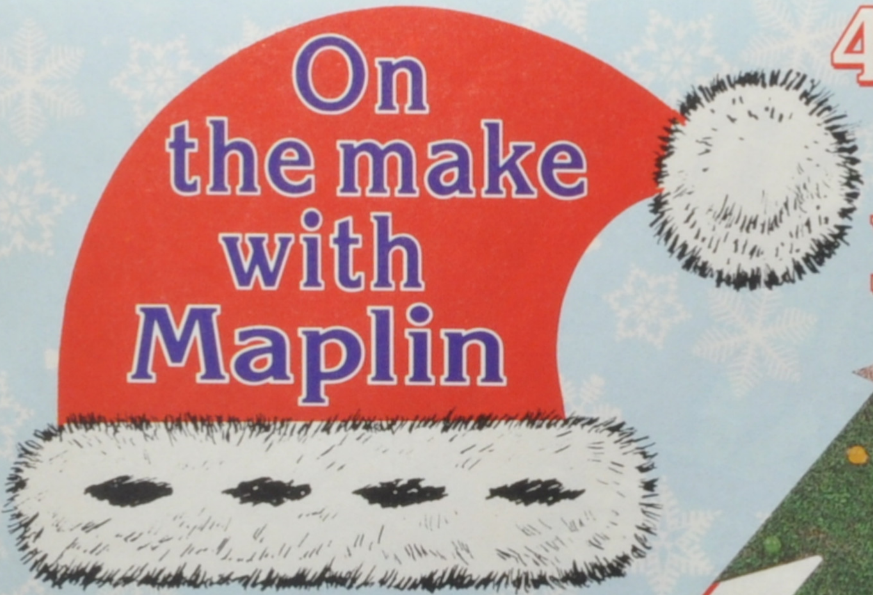

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LED Xmas Tree,
Order Code LP83E
£9.95.

2 PROJECT RATING

Fest-o-meter

Sort the 'Cold Turkeys' from the 'Christmas Crackers' this yuletide, with this simple to build 'Fest-o-Meter'. The unit uses the resistance of your skin to 'measure' your level of Seasonal Joviality, and lights the LEDs accordingly: see if Granny's had enough sherry trifle, or if Dad's drunk enough of the Christmas spirit yet. 'Hours of fun' are to be had trying to get all six LEDs to light by pressing your thumb on the contacts – if you succeed, you are rewarded with a festive tune! Full details are in *Electronics* Issue 60 (XA60Q).

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LED Xmas Star, Order Code, LP54J, £7.75.

2 PROJECT RATING

Jingle Bells, Jingle Bells!

Based around the UM66 series CMOS LSI chip, this module plays a 64-note melody of "Jingle Bells", "Santa Claus is Coming to Town", and "We Wish You A Merry Christmas". Certain to find many applications during the festive season, e.g., seasonal doorbell, toys, decorations, novelties etc. Full constructional details can be found in *Electronics* Issue 26 (XA26D).

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THE WAR OF THE DIGITAL FORMATS

The Sony MiniDisc and the Philips Digital Compact Cassette (DCC) are set to battle it out for dominance in the market-place. Both systems are aimed at the same sector of the audio market – that is as a replacement for the ageing, but very successful, compact cassette, which has been in existence for 30 years.

by Ian Poole

... Enter the Sony MiniDisc

Model MZ1.

Now with advances in IC technology and digital signal processing, significant improvements can be made to audio recording. Both systems have been well engineered and have a lot to offer, but their approaches are different in many respects. The Philips system uses a new tape which retains compatibility with the old cassettes which can still be played on new DCC machines. Sony have opted for a disc based system. Which of these two will gain dominance in this fiercely competitive market remains to be seen. But whichever one it is, it may take about two years before a clear trend is visible.

Why Digital?

Digital audio systems are well established in the Hi-Fi market. The Compact Disc (CD) was the first to appear in the consumer market, and gave a tremendous leap forward in performance over anything else which was available. With a virtually flat response, and minute levels of noise and distortion, the death knell of the traditional vinyl disc was sounded.

In view of this performance, the CD soon gained acceptance and sales quickly rose, reaching a level of about 800 million per year. Now CDs are the accepted medium for listening to high quality music recordings. This fact is borne out by radio broadcast stations, who almost exclusively use CDs as the medium for their music material.

Apart from their improved performance, CDs gained popularity because they were easy to use. No longer would the slightest scratch ruin a recording as happened with vinyl discs. Even if a small scratch appeared, this would be overcome by the digital error compensation in the player.

Another advantage was that CDs are much smaller than their vinyl counterparts. A CD can store up to 74 minutes of material and it is just over 4½in. in diameter. On the other hand, an LP has a 12in. diameter and a maximum playing time of about 60 minutes – and this requires the disc to be turned over unlike the CD.

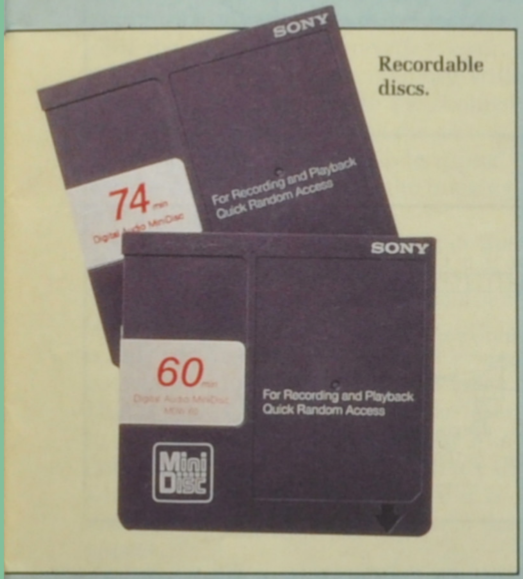
Finally being digitally controlled, it is very easy to programme a CD player to play tracks in any order, repeating some as many times as required. Most new players have this and many more facilities built into them.

Whilst the CD offers many advantages it is not completely without its drawbacks. The main one is that it does not lend itself to use in moving systems which are liable to vibration and knocks. Mechanical jolts can set the laser off track, thereby disrupting the play. With a growing requirement for 'Walkmans' and in-car systems there is a major gap in the market which can be filled. At the moment there are many in-car and portable CD players. However, the portable ones could certainly not be used whilst jogging. Whilst the in-car players are satisfactory for normal motoring and use sophisticated anti-vibration mounts, they are not always foolproof when it comes to bumpy roads and potholes.

Requirements

The compact cassette has given excellent service for many years, and will continue to be used in the future. However, to find out public opinion about the performance of the cassette a survey was commissioned. This revealed that over three quarters of the people surveyed were satisfied with the portability of the cassette.

In other areas people were not as enthusiastic. Over half the people interviewed were dissatisfied with the reliability of the cassette. Another of its disadvantages proved to be its random access capability with just under 50% of those interviewed saying they would like an improvement in any new system. Finally the sound quality did not live up to today's standards. Despite improvements in tape head technology and signal processing systems like Dolby, analogue cassette systems cannot live up to the performance offered by a CD. This lack of performance resulted in about a quarter of its users being dissatisfied.



Recordable discs.

Basic System

In view of the information obtained from the survey it was necessary that any new system should be portable, and capable of being used in a Walkman. It should also have improved sound quality, better access to different tracks and it should have a higher reliability than the analogue cassettes.

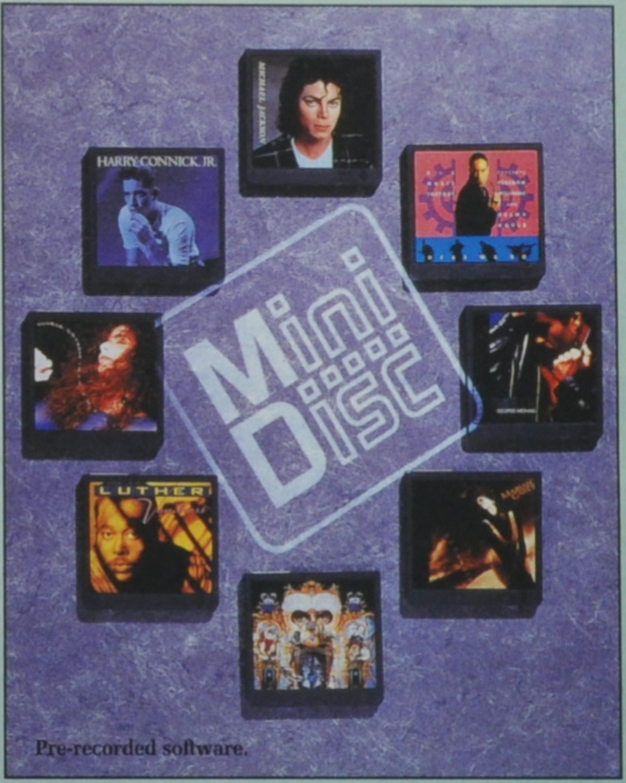
In fulfilling these requirements Sony decided to opt for an optical recordable disc system. This is hardly surprising since Sony have been developing optical disc technology in various forms for about twenty years. In fact they were involved in the initial release of the CD and they are one of the licensees.

After the launch of the CD much of their research was directed towards a recordable optical disc system for use in the computer industry. However, this research has now been put to very good use in the audio industry for the MiniDisc.

Not only have Sony had to develop a new form of storage medium in the form of the disc, they have also made an enormous investment in the development of the signal processing to enable the data to be stored on the disc.

The MiniDisc itself is smaller than a CD and this means that the amount of data which it can store is less. If it is to have the same playing time, then the actual amount of data used to store the sounds must be reduced. From this requirement Sony developed their ATRAC (Adaptive TRansform Acoustic Coding). This is very similar in its function to the Philips Digital Compact Cassette PASC (Precision Adaptive Sub-Coding) system because it reduces the amount of data needed by only storing those sounds which can be perceived.

Finally, the system has been made portable. When a portable CD player is used on the move, or in a car, sharp vibration can displace the laser. This can cause skipping or drop outs in the music. To overcome this the MiniDisc has a large RAM to store enough data to allow the laser to regain its place, thereby giving continuous play.



Pre-recorded software.

The Disc

As the name implies the disc is quite small. The actual rotating disc measures only 64mm in diameter and this is housed in a plastic cartridge measuring 72 x 68 x 5mm. This forms part of the overall disc and gives it an appearance very similar to that of a $3\frac{1}{2}$in. computer disc.

There are two types of disc. The first can only be used for playback. Once manufactured there is no way of recording onto them. These discs would normally be used for pre-recorded albums available from the shops. The front of the disc is clear and can be used for artwork. On the reverse side there is a shutter which protects the disc when it is not in a player. When the disc is inserted into a player the shutter opens to reveal the playing surface of the disc. This enables a laser to read the data stored on the disc in the form of pits and bumps virtually identical to those on a normal CD.

When reading a disc, the laser tracks from the centre where there is a lead-in area, to the outside. This is another similarity to the CD, but of course it is the exact reverse to the old vinyl discs.

Recordable Discs

It is in developing the recording technology that Sony has devoted a large amount of research effort. The fact CDs could not be used for recording until recently was one of their major drawbacks. As a result, it was recognised that it was very important that the MiniDisc should have this facility. Without this it was felt the system would have little chance of success.

The recordable discs are somewhat different, so allowing the discs to be overwritten an unlimited number of times. In terms of visible differences they have a shutter which reveals a section of both sides of the disc. In fact this is an indication that a different process is used to store data on these discs.

To achieve the recording capability, it was necessary to employ a system which, although different, would be compatible and use many of the same components. The solution, devised by Sony, is called 'Magnetic field Modulation Over-write' (MMO).

One of the keys to the operation of the system is the disc itself. This consists of four main films on the top of a plastic base. The films are very thin and have to be very uniform if they are to perform correctly. The key layer consists of a material called 'terbium ferrite cobalt'. This is located between two layers of silicon nitride with an aluminium layer on top. It is within the terbium ferrite cobalt where the actual data is stored.

The manufacture of these discs presented a number of problems which have been successfully overcome. The thin layers in the disc are deposited onto the plastic substrate using a process called 'sputtering'. In its basic form this technique involves evaporating atoms in a vacuum and then depositing them onto another surface under the action of an electric potential.

An improved system developed jointly by Sony and Materials Research Corporation in the USA, enables very uniform layers to be deposited. The system gives the lowest particle contamination level of any sputtering system to date. This leads to much higher production yields and reduced production costs. As a further benefit, the system gives a ten fold increase in speed over other systems which are available.

When recording, the laser scans the underside of the disc as it rotates and causes the magnetic material in the disc to be heated to 180°C, which is above its Curie temperature. At this point the material looses any magnetism it previously possessed. As the disc rotates the laser spot moves away from this point on the disc and it begins to cool down. As this occurs the magnetic material takes on the magnetic orientation of its surroundings. A magnetic head is placed above the disc and the flux which it sets up is the flux which is taken up by the sections of the disc as they cool down, see Figure 1. The laser acts as the 'key' that enables the recording to take place and the magnetic head writes the data onto the disc. Thus digital data can be transferred onto the disc, simulating the pits and bumps of the pre-recorded material.

This writing process has proved to be very reliable. It has a very large power margin and this minimises the distortion of the data on the disc. This means that there is much less jitter on the data than on other systems. In addition, the basic MMO system is very resilient to any disc tilt which may occur. Again this can cause data jitter. However, as the laser is only used to raise the temperature of the magnetic layer it has less effect on the magnetic spot shape. The result of this is that there is much greater reliability when the disc is played back. It also means that the same recording density as a CD can be achieved.

Playback

The playback system is just as cunning as the one used for recording because the two storage systems use the same pick-up even though they operate in slightly different ways. Despite the fact that it is dual function, the pick-up is based around the idea used for CDs.

For pre-recorded material a 0·5mW laser is focused onto the surface of the disc as shown in Figure 2. The light is reflected back off the surface and detected by two photodiodes also shown in Figure 2. The level of light reflected then indicates the presence or absence of a pit. If the light is reflected directly back this will indicate the absence of a pit. If there is a pit then the light will be diffracted and a much lower level will be detected by the diodes. These light level variations correspond to the digital data which can then be processed by the in-built electronics.

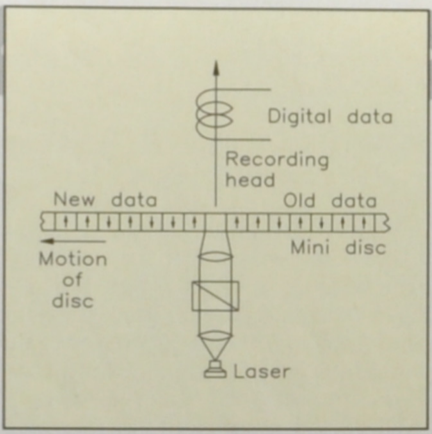


Figure 1. Recording on a MiniDisc.

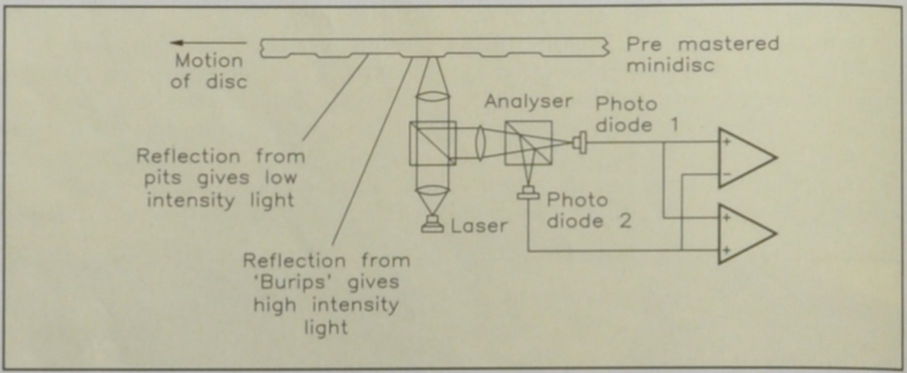

Motion of disc
Pre mastered minidisc
Analyser
Photo diode 1
Reflection from pits gives low intensity light
Photo diode 2
Laser
Reflection from 'Burips' gives high intensity light

Figure 2. Playback on a playback only disc.

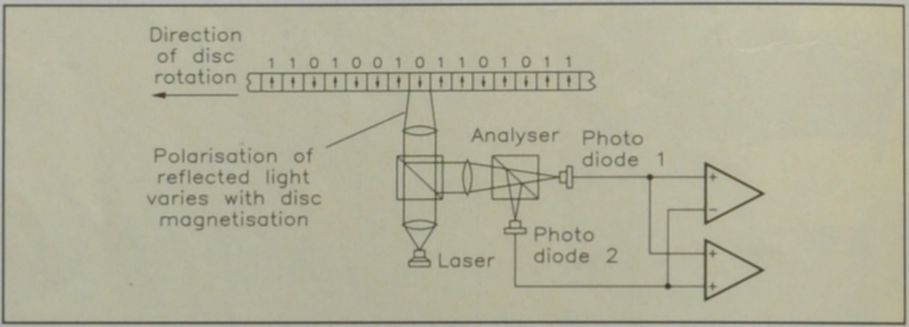

Direction of disc rotation
1 1 0 1 0 0 1 0 1 1 0 1 0 1 1
Analyser
Photo diode 1
Polarisation of reflected light varies with disc magnetisation
Photo diode 2
Laser

Figure 3. Playback of a recordable disc.

To read a recordable disc, the process is somewhat different, although exactly the same pick-up is used. The light from the laser, which is polarised, strikes the disc and is reflected back. However, the polarisation of the light is rotated slightly in a forward or reverse direction depending upon the magnetisation of the disc at that point.

The reflected light passes through what is called a 'polarisation beam splitter'. This separates the light of different types of polarisation and distributes it to the two photodiodes as shown in Figure 3. In this way the light reaching the photodiodes is dependent upon the amount of polarisation shift when the light is reflected and hence the magnetisation on the disc. Each photodiode converts its light energy into electrical signals and hence the digital data recorded on the disc is read.

Random Access

One feature of the CD which has been widely used is the ability to select tracks quickly and easily. Naturally, this facility has been built into the MiniDisc, but including this facility was not as easy as might be expected. There is little problem with pre-recorded discs because the same system used on CDs has been incorporated. The start and finish points of the tracks are known and these are stored in a directory on the disc. This directory, called the 'Table of Contents' (TOC) stores all the relevant information. When a particular track is required, the player refers to the TOC and moves to the correct position.

The system for achieving random access on recordable discs is rather more complicated. The system uses a 'pre-groove' to give the location information. These 'pre-grooves' are microscopic grooves which are pressed into the surface of the disc at manufacture and they give location information at intervals of 13·3 milliseconds.

To enable the player to find the correct start and finish points, the locations are stored on the disc in a reserved area called the 'User Table of Contents' (UTOC). This is very similar to the directory on a computer disc where all the locations of the programmes are stored.

This system allows random access of tracks to be performed virtually as fast on recordable discs as on the pre-mastered ones. This can be achieved to an accuracy of 13·3ms, which is more than adequate for most applications.

Memory

One of the major problems of the CD is lack of portability. Although portable CD players can be moved whilst they are playing, any shock can cause them to skip or jump. As a high degree of portability is necessary for the MiniDisc, it was important to incorporate a method of overcoming this problem.

As the disc is played, or recorded, the laser has to move across the surface of the disc, so a solution had to be sought to overcome the effects of shock. The actual method used was to incorporate a memory into the system. The data can be read from the disc faster than it is required by the decoding system. In this way it is possible to read data ahead of when it is required and store it in the memory. If the laser is displaced by a jolt the memory will start to empty as it continues to give out data to the decoder, until the laser finds its position again. When this happens, the memory will start to fill up again ready for another interruption in the data from the disc. In this way the music is not interrupted, despite any jolts displacing the tracking of the laser, see Figure 4.

Some figures are useful to illustrate the system. In current MiniDisc systems one Megabit memories are used. The data can be read in at a rate of 1·4 M-bits/s, but it is only required at a rate of 0·3 M-bits/s, giving up to three seconds of stored data. This is more than sufficient for the laser to regain its position, and on one demonstration it was just enough to allow the disc to be removed and re-inserted without any interruption to the music!

Obviously, in most cases the laser will not be continually jolted, and so a point is reached when the buffer memory is full. When this occurs data will cease to be read from the disc until the memory empties slightly and more data can be read in, so data is read into the memory from the disc in bursts as it is required.

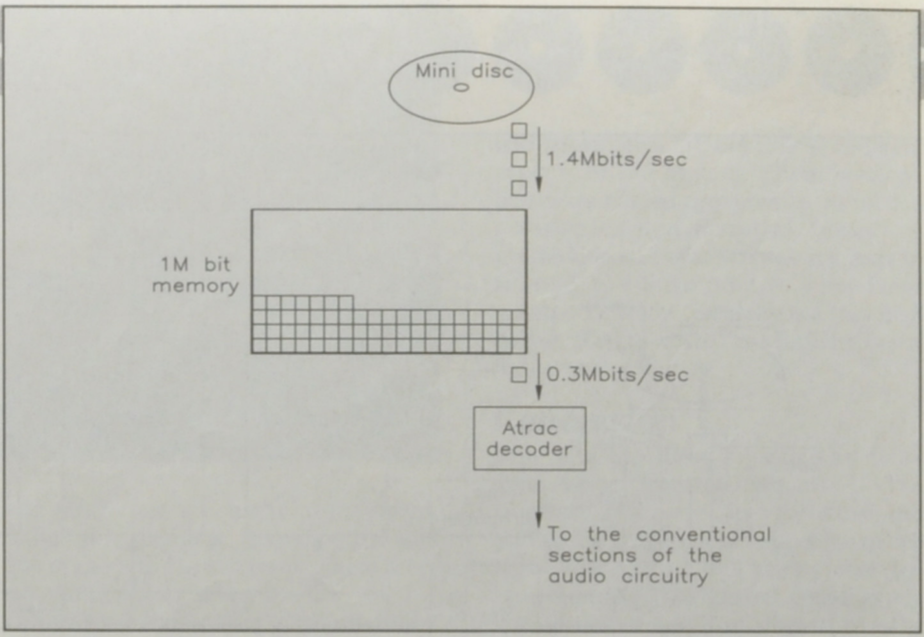


Figure 4. Shock resistant memory.

Data Compression

The MiniDisc relies on the small size of the disc to give it that all important feature – portability. Unfortunately reducing the physical size of the disc also reduces the amount of data which can be stored. If the data was stored in the same way that it is on a CD, then it would only be possible for a MiniDisc to give about fifteen minutes playing time. Clearly this is not acceptable, and as a result, Sony have developed a system of reducing the amount of data which needs to be stored. Called ATRAC, it is very similar to the Philips PASC system described in the article describing the Digital Compact Cassette in Issue 72 of *Electronics*.

A CD uses a 16-bit data sample every 0·02ms, regardless of the content of the waveform. However, such a large data word is only rarely needed, and with a degree of signal processing it is possible to identify only those portions of the signal which need to be stored.

During ATRAC, encoding the data is divided into time segments of up to 11·6ms, but in 0·02ms increments. Then using a system called 'modified discrete cosine transform' the waveform is analysed.

During the analysis, two main features are used – the first being the threshold of hearing. It is found that the sensitivity of the ear varies considerably with frequency, being at its most sensitive at about 4kHz and falling off above and below this frequency. Any sounds which are below this threshold, as shown in Figure 5, will not be heard, and can consequently be ignored by the encoding system.

The other effect occurs when two sounds are very close together in frequency. When this occurs it is found that the larger signal tends to mask the weaker one out as shown in Figure 5. The closer the frequency the greater the masking effect.

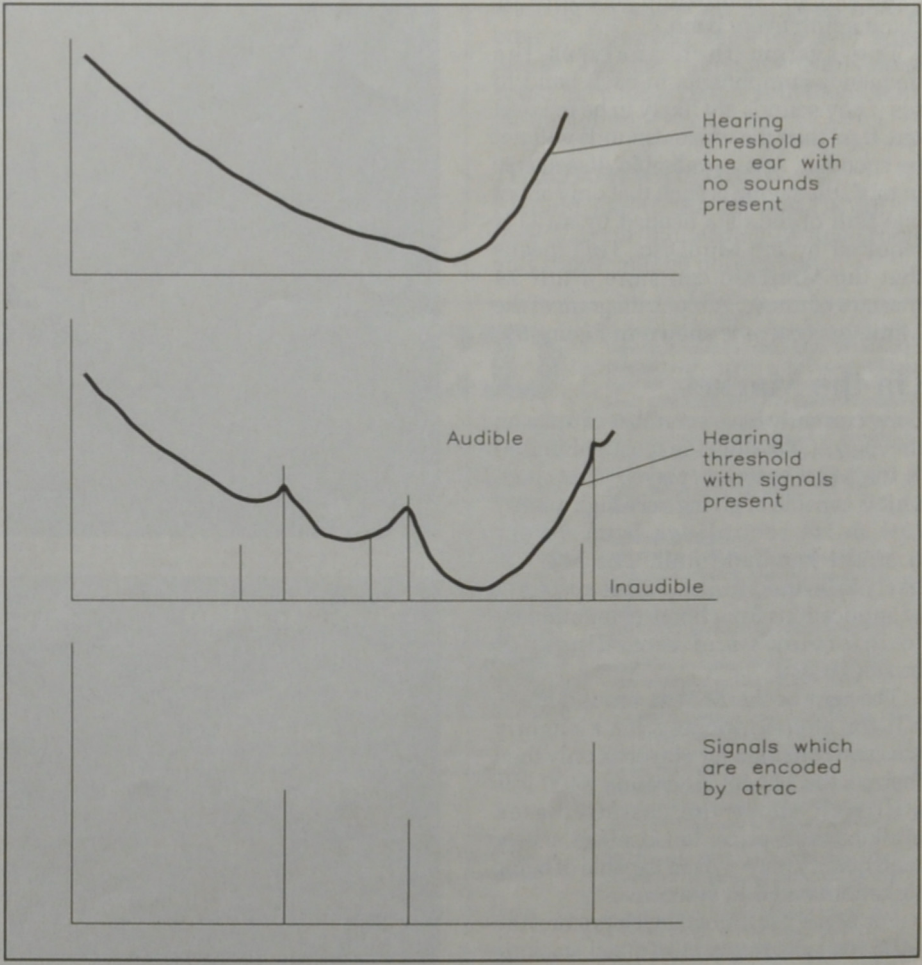


Figure 5. Signals encoded by ATRAC.

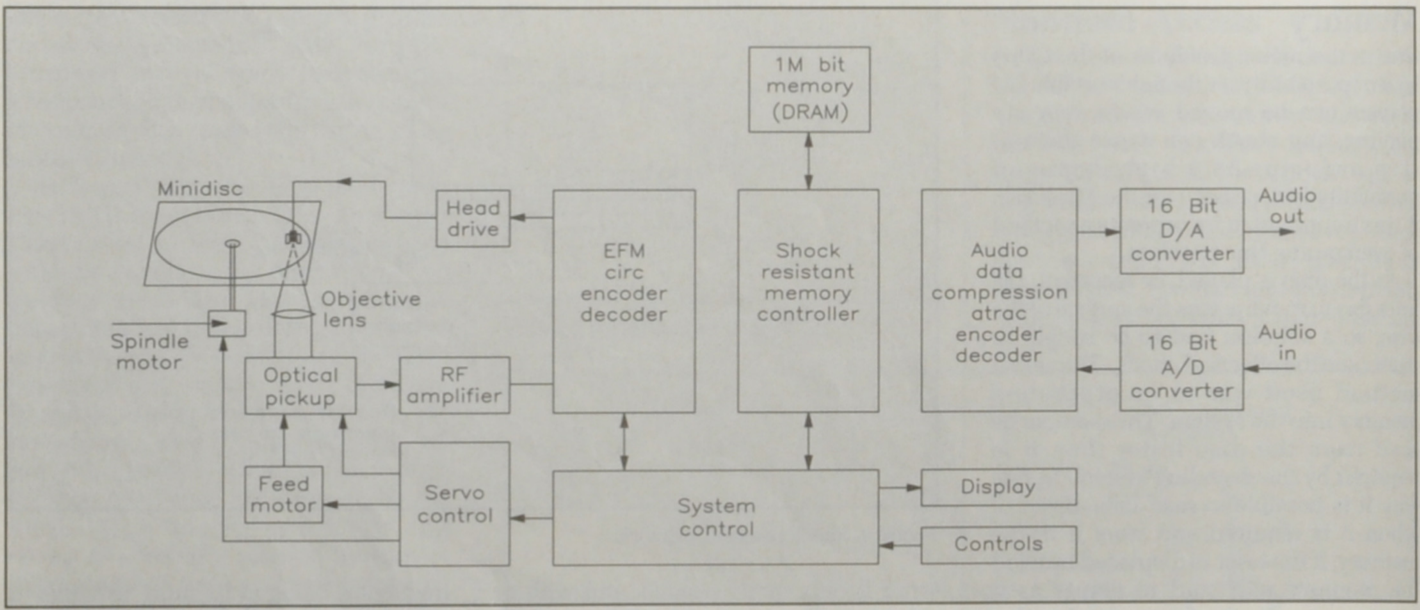


Figure 6. Block diagram of MiniDisc system.

To utilise this effect ATRAC splits up the audio into sub-bands. Unlike the PASC system, ATRAC uses different width bands dependent upon where they are in the audio spectrum. The reason for this is that the masking effect is not a direct function of the frequency difference in Hertz. As a result, the lower frequency bands are narrower than the higher frequency ones. Below 500Hz the bandwidth is about 100Hz and above this frequency the bandwidth increases by about a fifth every band.

The system then analyses the frequency components in each band to see if any sounds are likely to be masked out. If so, then the weaker sounds will not be encoded, saving valuable disc space. In total, the saving is such that only about one fifth of the data needed by a CD is required by the MiniDisc. This means that the MiniDisc can store a full 74 minutes of music. A block diagram of the MiniDisc system is shown in Figure 6.

On the Market

Sony currently have a number of units on the market. Possibly the most publicised is the MZ-1 recorder/player. This small unit is capable of giving very high quality low noise recordings from a very compact handheld unit. The MZ-1 is likely to be used in a very wide spectrum of applications from home entertainment to interviews and recordings for broadcast use.

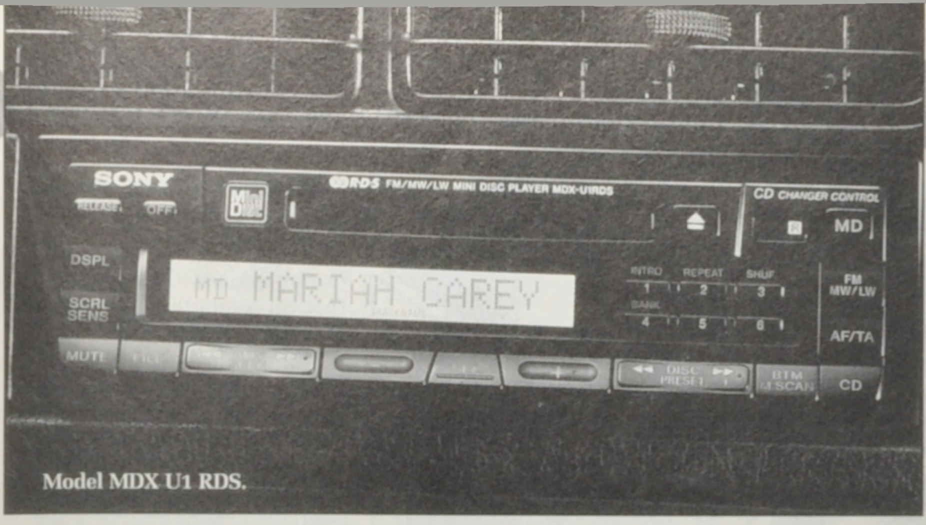
The cost of the MZ1 is around £500, but for anyone looking for a slightly cheaper Walkman for playback only then there is the MZ-2P. At around £400 it is still well above the cassette based Walkmans in price, but it offers a very high quality player, even capable of being linked into a Hi-Fi system.

For home use, Sony have launched the MDS101 which is a mini sized stacking unit which is designed to fit in with most

Model MZ-2P.

Specification

Channels:	2 (Stereo)
Frequency response:	5Hz to 20kHz
Dynamic range:	105dB
Wow and flutter:	Not measurable
Sampling frequency:	44·1kHz
Coding system:	ATRAC
Modulation:	EFM
Error correction system:	CIRC
Disc speed:	1·2 to 1·4ms (Constant Linear Velocity)
Record/playback time:	74 minutes
Cartridge size:	72 x 68 x 5mm
Disc diameter:	64mm


Model MDX U1 RDS.

home Hi-Fi systems. The cost of this unit is about £700.

Finally Sony have not forgotten the car market. Their MDX U1 is a top of the range in-car stereo system. The radio itself comes complete with RDS and the unit has a price tag in the region of £850.

Although the prices may seem high, like all new systems, prices are expected to fall when sales start to rise and other manufacturers come into the market.

Currently a large number of other companies are interested in the MiniDisc system. Kenwood, Sharp, Sanyo, Denon, Akai, Aiwa and many other major manufacturers have licences. In view of this it should not be long before a wide variety of units are ready for demonstration or actually in the shops. When this happens, it is expected that the prices will fall to a point where more people will start to buy them.

Recorded material is also important, and a number of record labels are distributing MiniDiscs including Sony's own label. Like the Digital Compact Cassette, the new discs are only available in a limited number of shops at present. When an assistant in one well-known chain store was asked whether they stocked them he apologetically replied they did not. Then as a reason he said they were rather small anyway!

The overall licensing process for MiniDisc technology is ongoing. In May 1993 a total of 53 different companies had agreements for the use of different aspects of the system. There were 32 hardware related agreements, 18 related to pre-recorded material, including production and custom pressing, and 18 related to blank media. This large number indicates that there is a very high degree of support for the MiniDisc in the industry.

Conclusion

The new MiniDisc system has many good design features built into it. The small size of the disc, its easy of use, and portability will no doubt appeal to many. However, behind this the system has been cunningly engineered, enabling two very different types of disc to use the same pick-up. In addition, the recording surface is protected in a case which is an integral part of the disc. This is obviously a great improvement, as any user of computers will be able to testify when comparing the $3\frac{1}{2}$in. discs against the $5\frac{1}{4}$in. ones.

However, despite all these advantages, many people will see it as yet another medium for which they will need to build up a completely new library of music. In this area the Philips DCC system has a distinct advantage, but it does not have the random access capability.

It will take some time for the market trend to be discerned. Most people are waiting to see what happens before buying. However, there is a very large degree of industry support and this alone could force the acceptance of this system for the future.

Acknowledgment

I would like to thank Sony UK for all their help in the writing of this article and supplying the photographs.

Terminology

Term	Meaning
DCC	Digital Compact Disc
CD	Compact Disc
ATRAC	Adaptive TRansform Acoustic Coding
PASC	Precision Adaptive Sub-Coding
MMO	Magnetic field Modulation Over-write
TOC	Table Of Contents
UTOC	User Table Of Contents
RDS	Radio Data System

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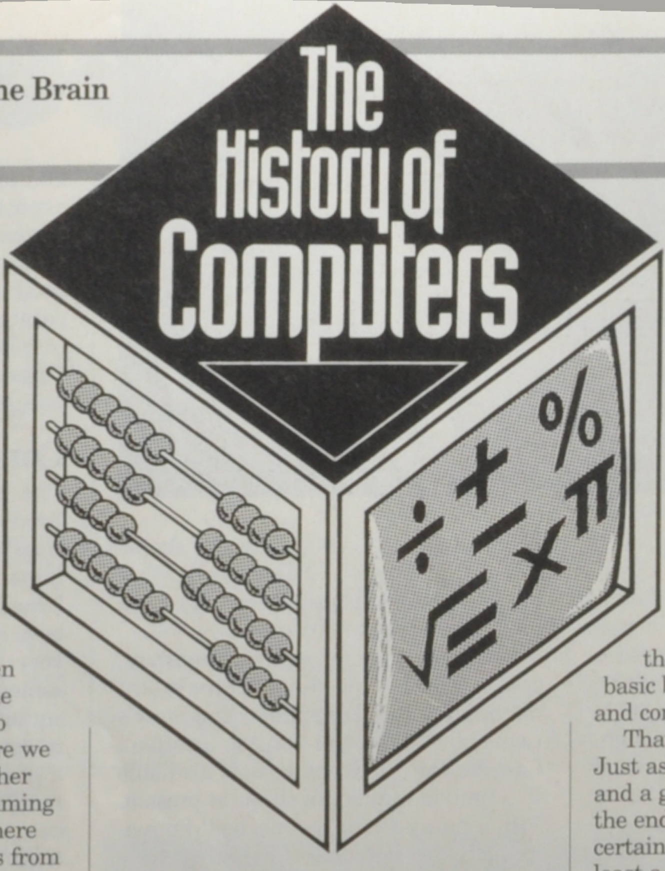
The History of Computers

10. The Future – Towards the Brain

by Greg Grant



The building of an electronic 'brain' is an idea that has been around for at least half a century, and if the concept has a father, it is the British computer scientist Alan Turing, of 'Turing Machine' fame. Before this dream can become reality, however, the electronic hardware will have to be reduced in physical scale quite considerably.

The total area of the average modern Large Scale Integrated circuit (LSI) is already minuscule, yet it has to become a great deal smaller still to come even moderately close to the scales of the brain. So what have we got to do to achieve this level of technology? Are we working towards this goal now, either consciously or unconsciously? Assuming we are, can we succeed, and will there be any other technological spin-offs from the development work?

All of these questions require a writer to brashly push his way into a field littered with the remains of those who have gone before – technological prediction. That said, let's take a look at what's happening presently and what it may lead to in the next century.

To begin with, we've come a long way this last half century or so. Forty eight years ago there wasn't a single computer in the world. Presently there are many millions of them, and in another half century they'll be as common as the change in your pocket.

A modern feature-laden digital watch, for example, does far more computing that either ENIAC, or the MIT's 'Whirlwind', ever did. What's more, the cost of computing has been reduced drastically over the same period, indeed by a factor of around ten million, according to one report.

Present-day microprocessors, for example, carry out some ten million operations per second, burning up about 1W of power in the process. In energy terms, a single chip carrying out one operation consumes around 10^{-7} joules whilst the computer, of which the chip is but a minute part, uses up about 10^{-5} joules per operation. This means that the entire machine is only some two orders of magnitude less efficient than one of its integrated circuits.

The transistors the chip contains currently have minimum dimensions of 10^{-6} metres, or 1 micron (1µm). By the year 2000, the computer industry will have reduced these measurements further by a factor of ten or thereabouts. Impressive really, isn't it? Yes – provided you know nothing about the brain and its capabilities.

To begin with, the human brain contains some 10^{16} synapses at which a nerve pulse arrives ten times every second or so. In short, the brain carries out around 10^{16} operations in a second, each of which consumes about 10^{-16} joules of energy. This makes it infinitely more efficient than present-day computer technology, and about a factor of ten million more efficient than any computer technology we can imagine. Hence computer science's interest in the brain. But how close are we to approaching this sort of efficiency?

Presently charging up the gate of a small transistor takes around 10^{-13} joules. In another decade, this figure will have come down to around 10^{-15} joules, beginning to come close to the sort of energy economy of the brain.

The Italian electronics giant Olivetti recently announced its A5 computer. It will have the performance of a laptop in the size of an electronic organiser or, as they are currently called, a palmtop.

Then there are Flash Memory ICs, which retain their information when the power has been removed. Presently the Intel Corporation has put twenty of these ICs onto what it terms a 'Flash Card', which gives some 20M-bytes of storage on a piece of plastic having all the bulk of a Diners Card. What's more, the Microsoft Corporation has developed software for it, which means that the card can mimic an operative hard disk.

In the autumn of 1991, IBM announced the development of the first polymer that has a photo-refractive effect, in which light causes the electrical charges within the material to move, altering its refractive index. This could mean optical storage devices capable of holding 10^{8} bits of information on an area the size of a full stop.

This discovery is timely, for many research scientists and engineers reckon that we've reached the limit of inter-chip speed and handling capacity, due to the increasing difficulties of IC manufacture. Consequently, optical computers have become a distinct option.

Optics are inherently parallel, and since light signals don't interfere with each other, communications channels can be far more densely packed than their electronically-signalled counterparts. They therefore offer the possibility of huge parallel systems operating at far higher speeds than is possible with electronics. The photon could therefore replace the electron as the basic building block of future computer and communications systems.

That, though, is some years away yet. Just as thermionic valves got smaller and a great deal more efficient towards the end of their active lives, so also are certain types of ICs. In fact there is at least a couple of orders of improvement to be had from the present generation of solid state devices.

For example, current chip-packaging techniques are such that only a tenth of the package is actually used by the IC. If inter-device connection techniques were to be improved, the amount of chip space required could be reduced considerably.

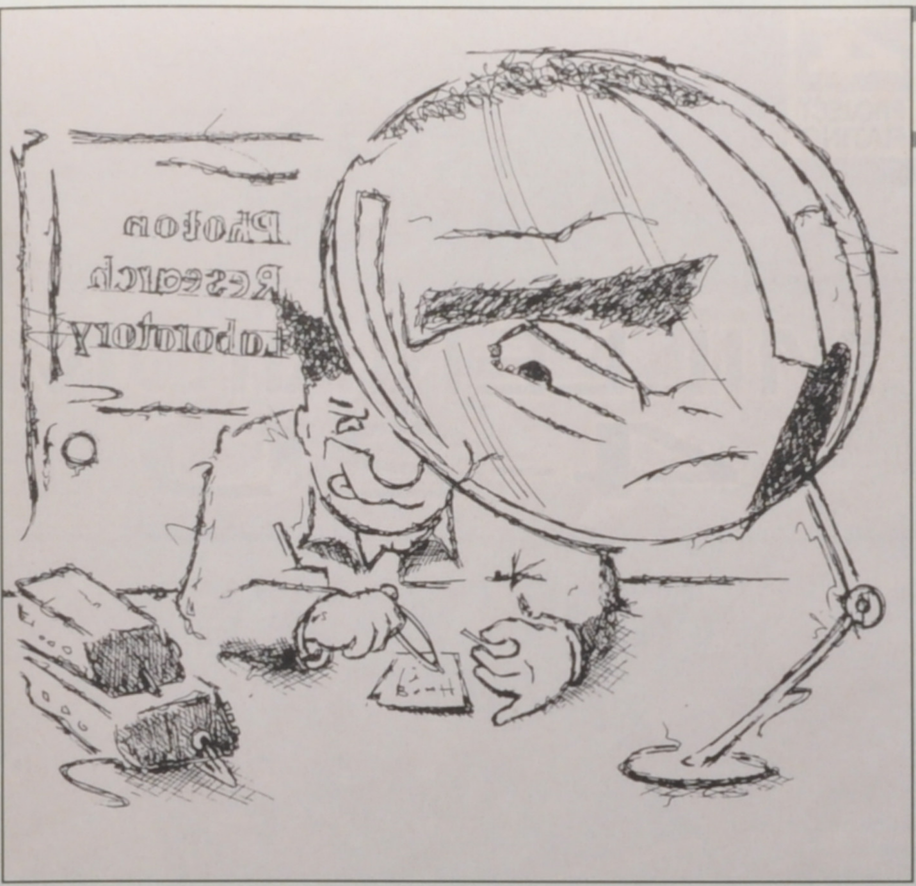
While a micron is minute on a human scale, it is massive on an atomic one. For example, a 1µm piece of semiconductor material is a 'bulk' material. Once you bring the dimensions below 20nm, or some 35 atomic layers, it isn't, and thanks to the development of molecular beam epitaxy, a technique for depositing atoms layer by layer, such thin material layers are now possible.

In fact, it's becoming a feat in itself to keep tabs on all the developments going on in computer technology. In 1989, for example, the generally accepted modem standard was 1,200-bit/s. A mere three years later this had risen to 9,600-bit/s.

We can safely say that hardware will continue its relentless advance, as indeed it has done these last forty-odd years. As to the spin-offs, they will manifest themselves as obtusely as, one suspects, they've done in the past, one example of which is the 'Clean Room'.

This byproduct of computer manufacture is presently so efficient that one such area contains no more than a single half-micron particle of dust per cubic foot of air. This means that such areas are 1,000 times cleaner than the average operating theatre!

Equally we could end up with a product which – although difficult to relate to computers – has a universal use. Teflon was such a byproduct of the Space Race and, as we approach the atomic level, who knows what properties we'll discover in a variety of materials and subtle combinations of substances.



So much for what can, fairly accurately, be deduced from what we know currently. Babbage, you may recall, realised early on that his brainchild needed power, although it transpired that the power he'd envisaged using was already past its prime.

This didn't nullify his deduction, but merely made it dated. We must guard against making similar mistakes. Presently, semiconductor LASER techniques are advancing at a faster rate than computer technology generally. Such devices will have a considerable influence on the design and ergonomics of future optical computers, amongst other things.

Looking further ahead, there is the on-going development of superconducting materials, an area of scientific technology which is still very much in its infancy, yet one whose applications in computer technology could be crucial. Equally it may be that a technique or device that appears original or advantageous turns out to be theoretically more stunning that its practical application. One past example of this sort of paradox was the Wankel engine. Here too we must be prepared for the occasional disappointment, for that which reads better than it lives.

That said, we are likely to be as surprised over the next forty years as we have been over the last forty. Those past developments weren't simply surprising – they changed our world completely. We are, I suspect, in for another resounding repetition!

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4
PROJECT RATING

THE MAPLIN MILLENNIUM 4-20

20W VALVE POWER AMP

Part 1 OVERVIEW & PSU

There has been an increasing resurgence of interest in valve amplifiers in recent times. While rival magazines have featured odd valve circuits over the past few years (if sporadically), the great empire of Maplin has mainly ignored the subject – until recently.

Most commercial, ready-made valve amplifiers are classed in the high-power, Hi-Fi end of the market, and at this giddy altitude prices may begin at £1,200 or £1,500 and go up to however much you think you ought to pay, in one instance, the equivalent to the price of a house (honest!).

Designed and Written by Mike Holmes

THE resurgence has also affected many members of the *Electronics* staff, here at Maplin. The idea to produce a valve amplifier was sparked off by Graham Dixey's series of features on 'Valve Technology', and somebody's suggestion to follow this up with more projects.

Further enquiries by this author revealed that at the more modest, lower powered end of the audio amplifier spectrum, nothing much is available in valve form. Furthermore, any ambitious ideas about 40 or 50W designs were curtailed by the need to moderate costs (to you, the customer) to a reasonable level. Valve amplifiers always cost much more than their transistorised counterparts, mainly because of the amount of 'ironmongery' involved. This may have something to do with why the 'at least one stereo in every household' situation is more a modern-day phenomenon. The result of all this was to settle for a stereo 20W design, which we present here, and it fills a gap which has been left empty for a *very* long time.

Concept

In order to help spread expenses while putting it together, the complete system has been organised into just two separate kits. In this way each kit can be bought and built as and when funds permit, as an alternative to a large financial outlay all at once at the outset. These comprise one complete mono amplifier module, and a power supply unit as a separate module. To complete a stereo power amplifier, you will require two identical amplifier kits, and the PSU. The PSU is able to supply a pair of amplifiers, but it can also cater for a mono version.

A finished stereo version of the Millennium 4-20.

FEATURES

- Class AB1 Push-Pull Output
- Non-Hybrid Traditional 4-Valve Design
- Simplified Construction Using PCBs
- Expandable Modular Concept
- Mono or Stereo Options
- No Setting Up Required
- Minimal Test Equipment Needed

APPLICATIONS

- Domestic Hi-Fi/Stereo Music Systems
- Small-Scale Public Address
- Musical Instrument Amplification

PSU Kit Available (LT44X) Price £49.95 C6

(Other variations, include three-way and 'quadraphonic', or a pair of 'monoblocs', which will require two PSUs.)

The fully enclosed chassis (in this case, for the PSU) is common to all the units in the design, and all can be joined together to make a complete assembly if desired. More details about how to do this will be presented in Part Two.

The main advantage of using the individual chassis is, apart from allowing each kit to be completed individually, that each unit will be self-contained and screened from its neighbours, communicating with them only via holes made for wiring looms. For the Power Supply Unit, this is restricted to the earth, HT supply line and heater pairs – only up to twelve wires in total.

A Brief Description of the Amplifier

Part One of this project is primarily going to deal with the construction of the PSU section, but a brief description of the actual amplifier is in order, so at least you will know what it's about!

Figure 1 shows a block diagram of the amplifier (primarily intended as one of a stereo pair) while the circuit diagram is shown in Figure 2. It is thoroughly traditional in design and is typical of high quality power amplifiers of the 1950s and '60s. It offers an output of up to 20W r.m.s. into 8Ω, operating in class AB1, and has a total distortion figure of around 0·4%, and an input sensitivity of 220mV. A more detailed description will be presented in Part Two; suffice to say for the moment that, like all class B amplifiers (including solid state ones), it has three distinct stages (as in Figure 1), these being a push-pull power output stage, a preceding phase-splitter stage (even transistor and IC power amps have phase splitters, although they are not obviously clear to see), and some form of front-end stage which can incorporate a negative feedback loop to set the gain and control the overall circuit.

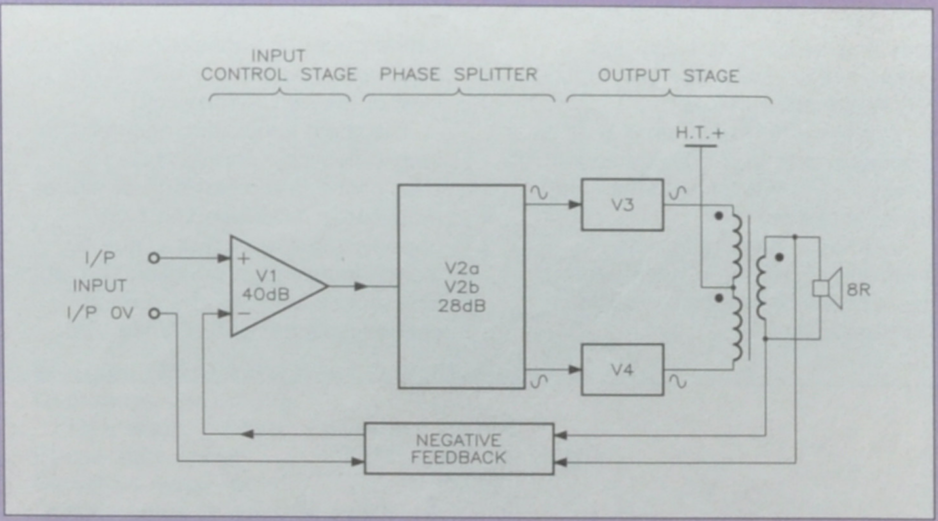
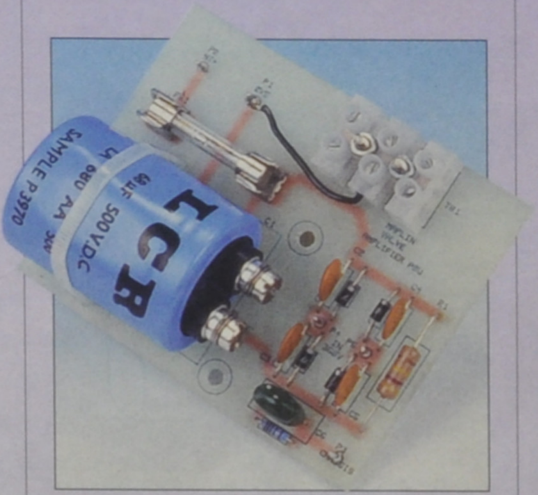


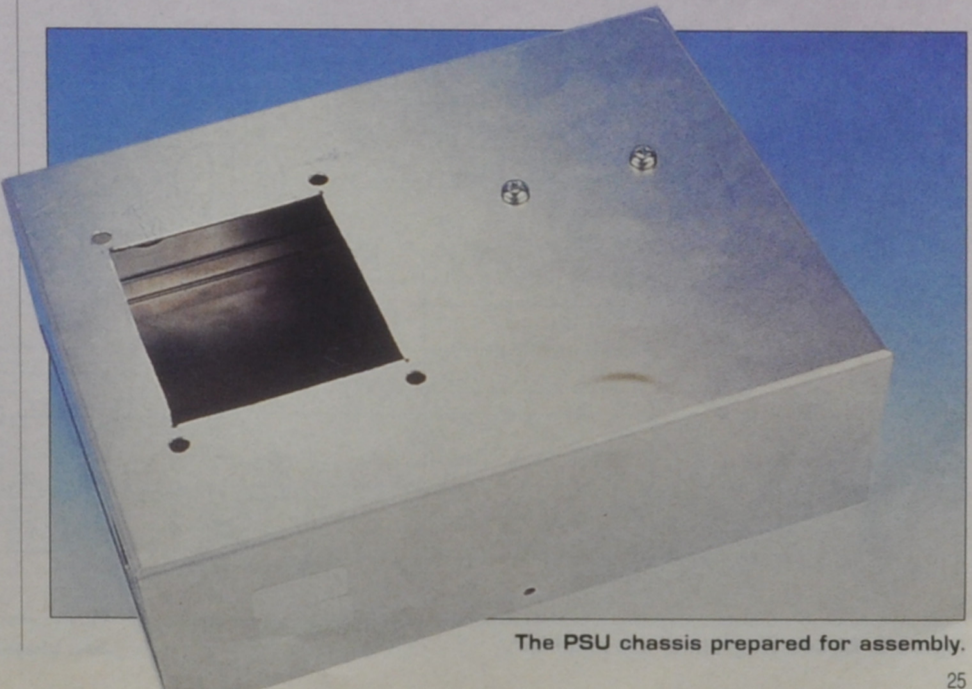
Figure 1. Block diagram of the 'Millennium 4-20' amplifier.

The brief history of how this design evolved is interesting in itself. A rough idea was 'cobbled' together using scraps of data gathered from here and there, and then, as more detailed data was obtained, it began to take on a more practical aspect. At this point the output stage was more or less established, and the specification of the output transformer determined. This was a crucial step, because the design of both the remainder of the amplifier and the power supply hinges on that of the output transformer.

Ignoring pressure from other sources (sorry, Alan!) to adopt a 'concertina' type phase splitter, where equal value cathode and anode resistors are used to derive the opposing-phase drive signals,



Assembled Power Supply Unit PCB.



The PSU chassis prepared for assembly.

I stuck to the intention of using the long-tailed-pair, push-pull configuration (V2a and b in Figure 2). This was because:

1. the unity gain version is already demonstrated in the Velleman K4000 design, and I wanted to show the other variation;

2. I know this configuration from experience and have used it successfully before for various purposes; and

3. it reduces the number of signal coupling capacitors otherwise required. Apart from that it has a kind of elegant symmetry.

The main argument against the long-tailed-pair configuration is that there is a mismatch of signal amplitudes between the two opposing phase outputs, due to losses incurred in coupling the signal through to V2b via the common cathode connection. (While V2a operates in common cathode mode and is an inverting amplifier, V2b is a non-inverting amplifier working in commoned signal grid mode, receiving its input at its cathode.) The result is that the (non-inverted) output from V2b anode is at a slightly lower level than that of anode V2a, but this is not a huge error and is easily corrected (to be discussed in Part 2). This is in part due to sensible design of the

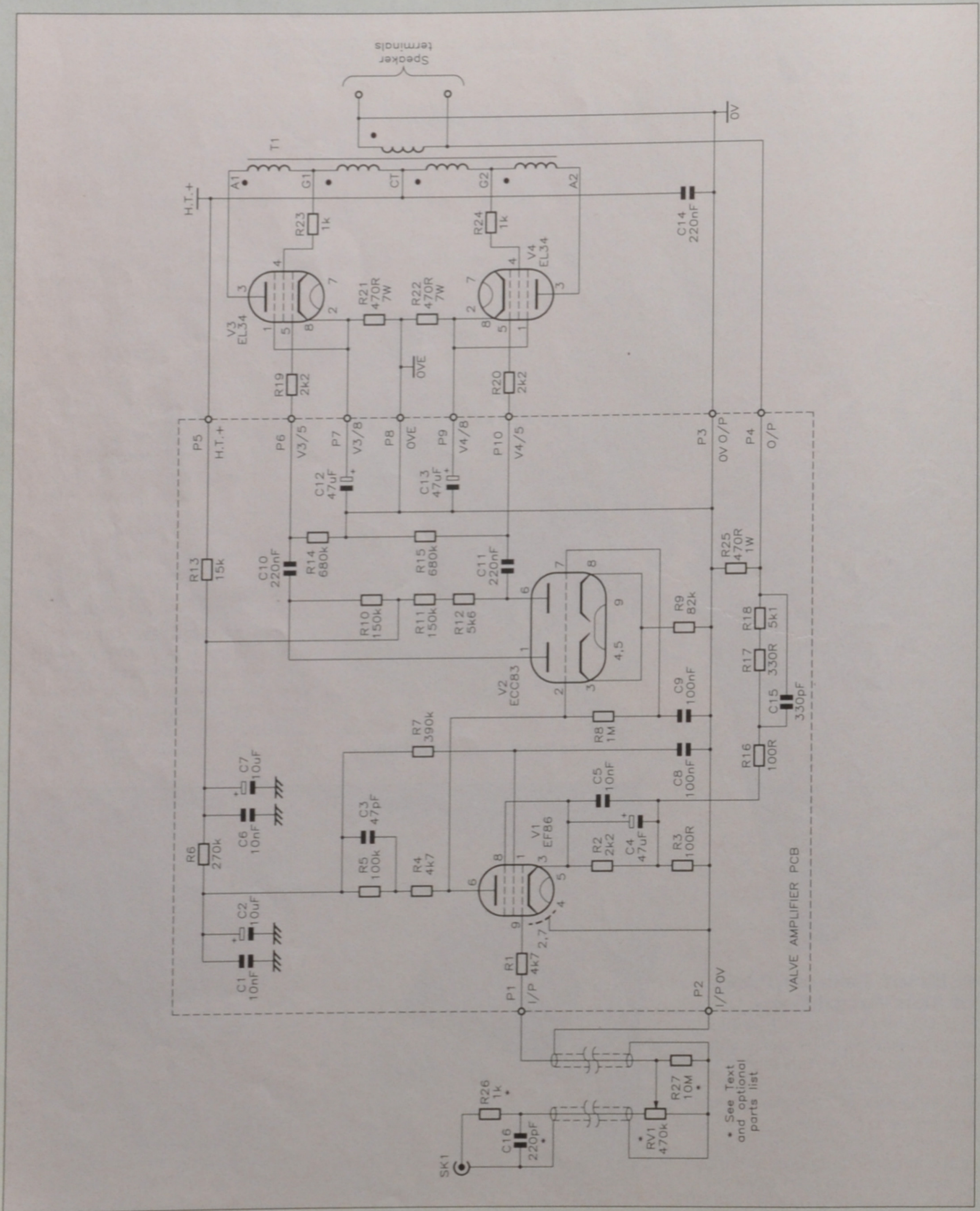


Figure 2. Circuit diagram of the amplifier.

stage, and the fact that the ECC83 was developed with this kind of application in mind, amongst others, and although the otherwise obtainable, effective amplifying power of each valve is reduced by half, the stage still manages an open loop gain of 28dB with close symmetry.

However, not using the unity gain splitter, which must be preceded by an amplifying stage as it has no signal gain of its own, and which could incorporate the negative feedback loop, meant that a further valve was needed at the input to fulfil this function. The EF86 was chosen, mainly because it is a single device in one 'envelope' (valve-speak describing the glass tube). Having to use one half of a triode pair, for instance, would have defeated the object of being able to treat one amplifier as a complete, self-contained, single entity, and a complete single module, as explained earlier.

Shortly after this, more data became available, namely genuine Mullard circuit designs, and it turned out that what I had put together was very similar to an original Mullard design published in 1962! From this information the design was finally 'beaten into shape' in the form shown in Figure 2 – for instance, one detail overlooked was that many valves have one thing in common with some modern analogue ICs; the peripheral circuitry must be adapted to the device, and not the other way around. (The main revisions affected the values of resistors associated with V1.) The proposed output transformer design was nearly correct also (amazing!) and needed only minor adjustment. The final specification is listed in Table 1.

The result of all this is that the final design, as you see it now, is so close to the Mullard original as to be virtually identical – simply because Mullard had already worked out all the finer design details beforehand; I merely rediscovered the problems that they cured along the way. Mullard's circuit has been public domain information since early times, and the amplifier had, to use an expression, become 'a legend in its own lunchtime. . . .'

Amplifier type:	Class AB1 'Ultra-Linear'
Line supply voltage (HT):	400 to 450V DC
HT current consumption:	125mA nominal (HT = 440V)
Heater current consumption:	3·5A
Maximum output power:	20W r.m.s. (27W absolute maximum, HT = 440V)
Gain:	30dB
Input sensitivity:	220mV for 20W Output
Frequency response:	25Hz to 30kHz ± 0·5dB @ 20W –3dB @ 75kHz @ 20W <10Hz to <40kHz ± 0·5dB @ 1W
Risetime (1kHz square-wave):	4μs
Overshoot and ringing (1kHz square-wave):	≈10%
Phase shift error:	20° @ 20kHz
Signal-to-noise ratio:	89dB
Output noise (input grounded),	
hum:	<3mV peak
white Noise:	<2mV peak
Harmonic distortion:	0·05% (0·1% @ 27W)
Intermodulation distortion:	0·7% of carrier (1% @ 27W)*
Beat-note distortion:	0·25% (0·3% @ 27W)†
Output impedance:	<0·2Ω
Damping factor:	50 approx.
Output Transformer Details	
Primary anode-to-anode impedance ($R_{a/a}$):	6·6kΩ
Screen grid taps:	43% from CT
Winding distribution:	Five sections of interleaved primary and secondary windings
Speaker load matching:	8Ω only
Low frequency cut-off:	25Hz @ 20W throughput
Primary resonant frequency:	80kHz approx.

* 10kHz carrier modulated with 40Hz at a ratio of 4:1.

† Equal amplitude signals of 14 and 15kHz.

Items marked (*) and (†) are based on Mullard's equivalent prototype amplifier. Some of these values may vary slightly for different kit amplifiers.

Table 1. Specification of Amplifier.

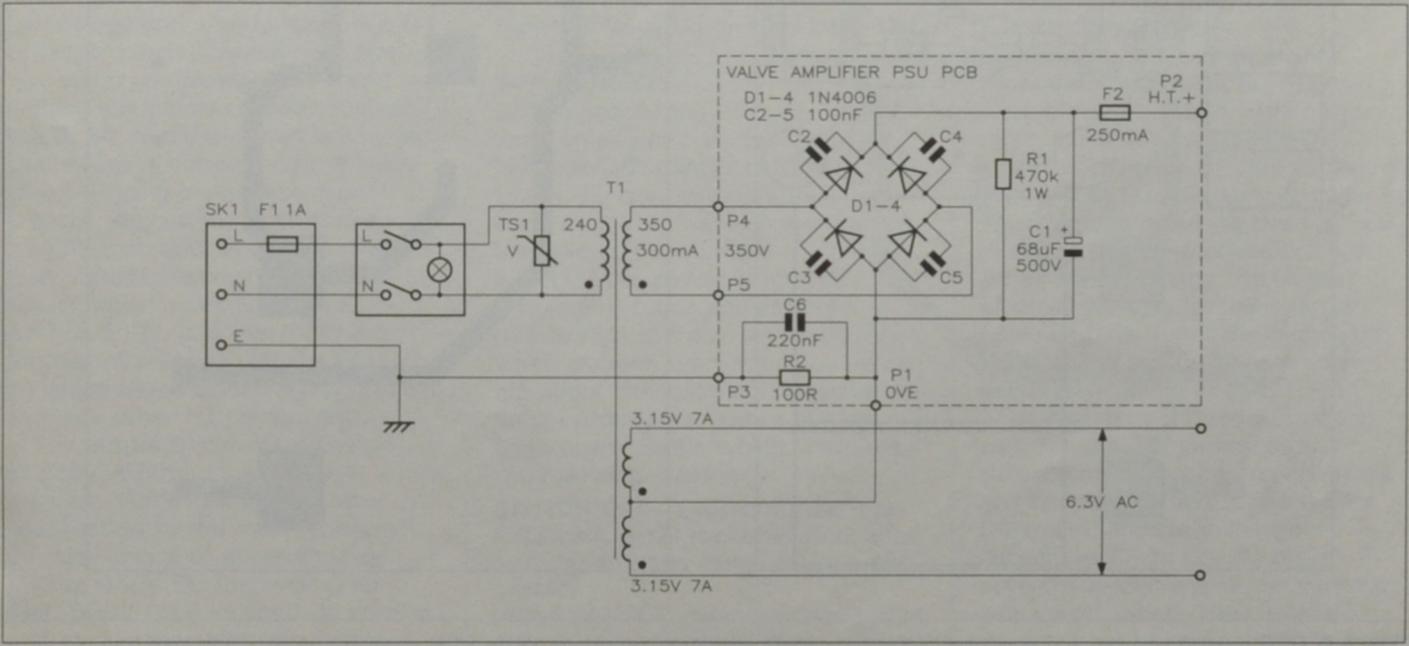


Figure 3. Circuit diagram of the power supply unit.

Valves versus Transistors

Why bother, you may well ask (especially you younger readers); aren't transistors supposed to be better, isn't that why they made the valves obsolete? It's not really a fair comparison; valves and transistors are as different as chalk and cheese. Semiconductors are simply more convenient to use compared with valves, which consume lots of power, take up a lot of physical space and output no mean amount of heat.

However, as signal amplifiers, valves have a superior linearity that may only be equalled by some FETs. This means that, as audio amplifiers, any harmonic distortion introduced practically consists of even harmonics only (2nd, 4th, etc.) in the case of triodes, i.e., there are few odd harmonics. Since the human ear follows a logarithmic law to interpret the scale of tones (as it does a logarithmic scale of sound levels), even harmonics arising from harmonic distortion go relatively unnoticed, whereas odd harmonics are detectable. One result of this – as borne out in listening tests – is the ability of this amplifier to handle a complex mix of musical harmonics and manage to keep them distinctly separate, instead of smearing into each other. This is quite apart from the unique transfer characteristic, the way valves actually handle the flow of electric current as nothing else does. If the *quality* of the sound is important then, for many afficianados, valves excel.

Transformer primary input voltage:	240V AC 50Hz			
Valve heater (secondary) circuit type:	Earthed centre-tap balanced AC			
Heater output voltage:	6·3V AC 50Hz (3·15V – 0 – 3·15V)			
Heater output current:	7A maximum			
HT secondary output voltage:	350V AC maximum			
HT secondary output current:	250mA maximum			
HT output voltages,				
no load:	480 to 500V DC			
single amplifier powered:	430 to 440V DC (half load)			
two amplifiers powered:	370 to 400V DC (full load)			
HT Ripple:	<6% of total DC at full load			
Power Consumption,	**HT**	**Heater**	**Total**	**Mains current**
single amplifier:	55W	22W	77W	>320mA
two amplifiers:	96W	44W	140W	<700mA
Cold switch-on mains in-rush current at full load:	>800mA			
Primary side protection:	1A 'quick-blow' fuse			
Main line DC HT protection:	250mA anti-surge fuse			
Unloaded or open-circuit HT reservoir discharge method:	Constant leakage resistor			
Unloaded HT reservoir discharge time:	1 minute approx., 500V to 0V			

Table 2. Specification of Power Supply.

The other component that may be regarded as 'highly suspect' as far as sound quality goes is the output transformer, essential for matching the valves' high output impedance to the low impedance of a loudspeaker, and I must admit that I myself have been guilty of believing audio transformers to be hopeless at carrying audio with any semblance of quality. This is a myth of course; if the item in question is horribly designed and crudely made this may be true. However, if well designed (and valve transformer design is a law unto itself, and almost in danger of being lost to posterity along with other 'ancient skills' like shoeing horses and thatching roofs), it's a totally different story.

The Power Supply Unit

The amplifier is not going to do anything for us however without a suitable power supply! Therefore the remainder of the text deals with constructing the PSU, which should be built and tested first.

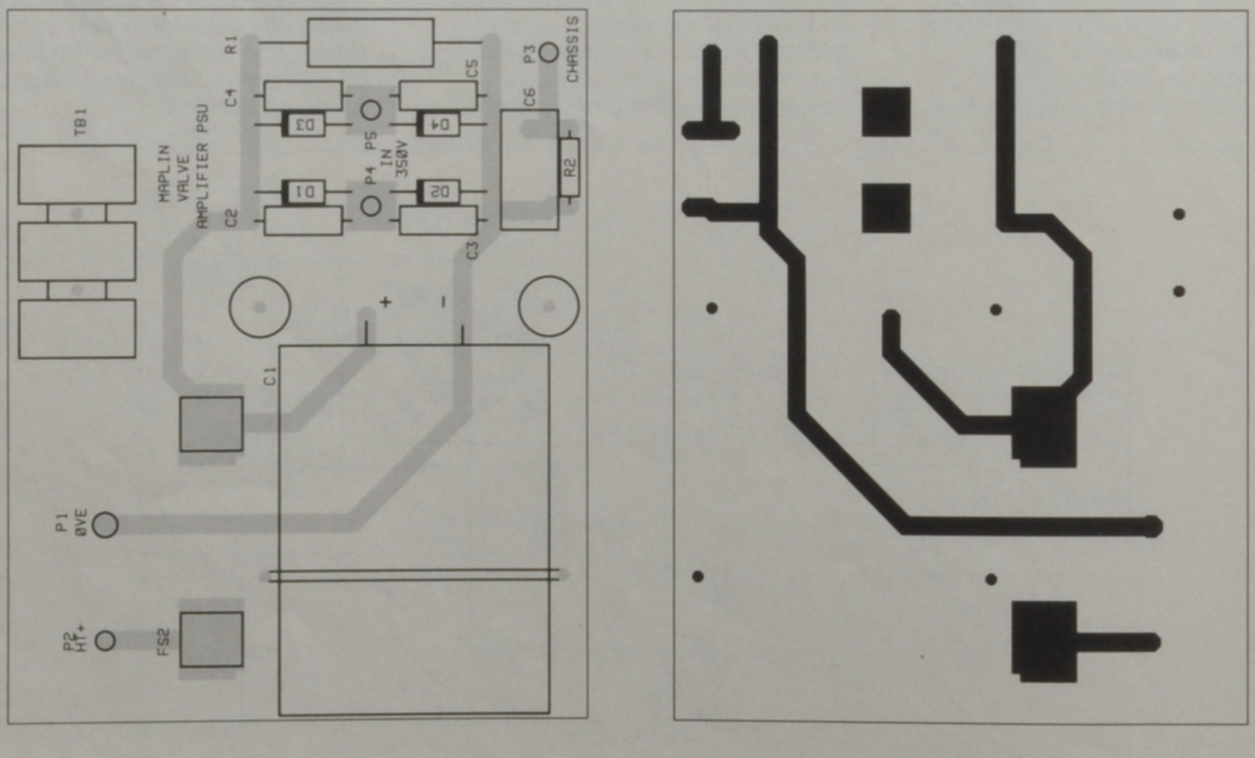


Figure 4. PCB legend and track. Important Note: for safety reasons the ready-made PCB *must* be used, since this has a solder resist. PCB track is shown here for information only.

Power Supply Description

The circuit of the PSU is shown in Figure 3, and the details of its power output is rather different to that normally associated with solid state circuitry! (see Table 2). There isn't really very much to it, the main component being transformer T1, whose function is to provide the HT source and the valve heater current.

Firstly, 240V AC mains power comes in via a fused and filtered euro inlet chassis socket SK1. Earth is directly connected to chassis through the metal body of the socket, while both Live and Neutral are taken to the DPST front panel on/off rocker switch SW1. From here it is applied to T1 primary.

The valve heater secondary is at the standard low potential of 6·3V AC, and has a centre-tap connected to 0V. This results in equal and opposite phases of 3·15V alternating around earth potential, and is the classic method of preventing hum injection into sensitive circuitry from heater wiring. In addition, this is further aided by all heater wires being communicated to the various valve heater pins as twisted pairs, such that the opposing electric fields cancel out.

The heater current output capacity of 7A may be surprising, but this of course is the main area where valves are wasteful of power. Most of this output is consumed by the four EL34 output pentode valves (for a stereo system), which are extremely current hungry (1·5A each). The remaining 1A is distributed among the remaining small-signal valves.

The HT winding is single phase, as opposed to the traditional bi-phase configuration, as a concession is made here to semiconductor technology and a bridge rectifier, D1 to D4, is used. It would have been nice to go completely 'valve' and employ a bi-phase rectifier such as the GZ34, but the diodes are by far the cheapest option, and the single phase winding that these allow greatly reduces the cost of the transformer also. In addition the peak voltage between any two points never exceeds the peak of 490 to 500V, and this minimises the risk of creepage on the PCB, on which these diodes are contained with the other HT components.

The output of the HT winding, of 350V AC (max.) at 250mA (approx. 100W), is applied after rectification to the main reservoir C1, charging it to approximately 400 to 450V DC (depending on load; 500V DC if no load). In parallel with this is the safety discharge resistor R1 (more of which later).

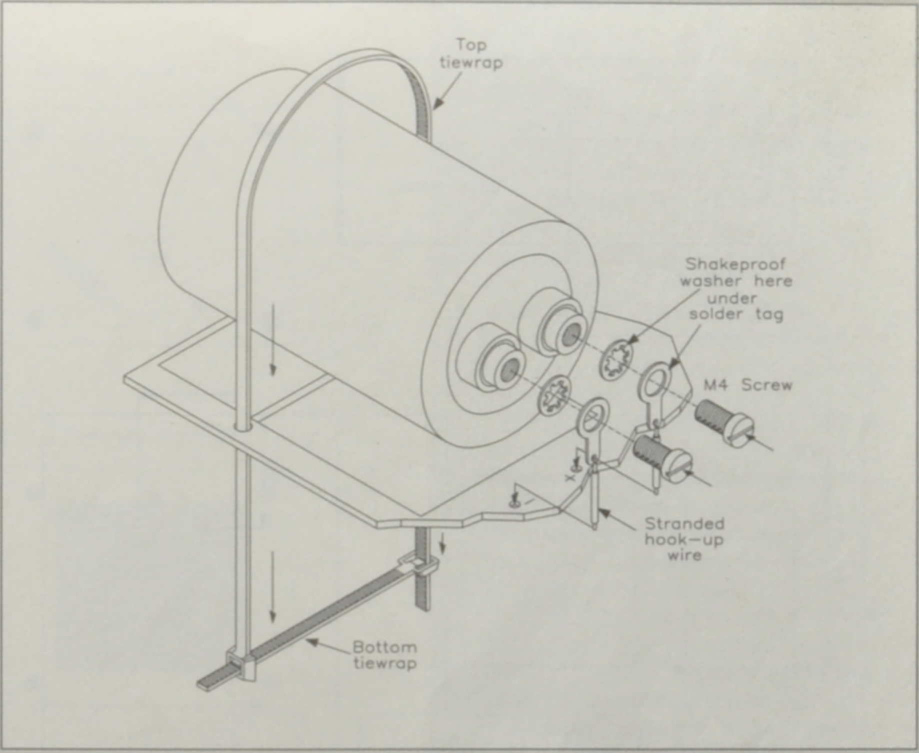


Figure 5. Mounting capacitor C1.

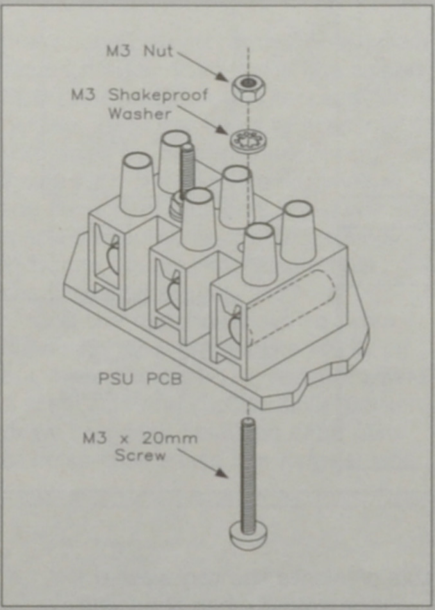


Figure 6. Mounting terminal block TB1.

WARNING!

Before proceeding with any kind of work on this circuit, take heed – high voltages **CAN KILL!** NEVER touch any high voltage part of the circuit with either fingers or uninsulated tools unless the power is OFF! While power is on, you should only touch any part of a circuit with an *insulated* test probe when *required*. Every time you switch off, adopt the following industrial safety procedure, known by the anacronym 'SIDE', which spells out the following steps:

SWITCH OFF – Switch off the main PSU front panel rocker switch, and switch off at the mains outlet wall socket.

ISOLATE – Pull the mains lead out of the mains inlet socket at the back of the PSU.

DISCHARGE – Discharge the main line HT reservoir capacitor to zero volts (**NOT** with a screwdriver!).

EARTH – Earth the main line HT to chassis 0V with a leakage resistor to prevent any electrolytics recovering a charge from their own dielectric absorption.

In the design of the PSU 'discharging' and 'earthing' is automatically taken care of by R1 in the PSU circuit. Please note that it may take the resistor up to 1 minute to completely discharge the unloaded HT to 0V. To make doubly sure, you **MUST** test the main line HT with a multimeter set to high DC volts (e.g., 500 or 1,000) before touching any part of any circuit. This shall hereon be referred to as 'the SIDE procedure'. **DON'T CUT CORNERS!**

Construction

Building the PSU will be mainly carried out in two parts. To begin with it may be easier (and, perhaps, more familiar) to assemble the PCB.

With reference to the PCB legend Figure 4 and the Parts List, begin by inserting and soldering the five PCB pins into their respective holes at P1 to P5. Note that the largest of these will only fit in the larger hole near the top of the board, P1 ('0VE'). This will be the common earth terminal for the PSU.

Fit resistors R1 and R2, noting that R1 is a 1W carbon type. Before any more bulky components are installed, fit and solder diodes D1 to D4, and ceramic disc capacitors C2 to C5. Do make sure the diodes are all the correct way round, where the cathode marker band at one end of the body of each aligns with the white marker

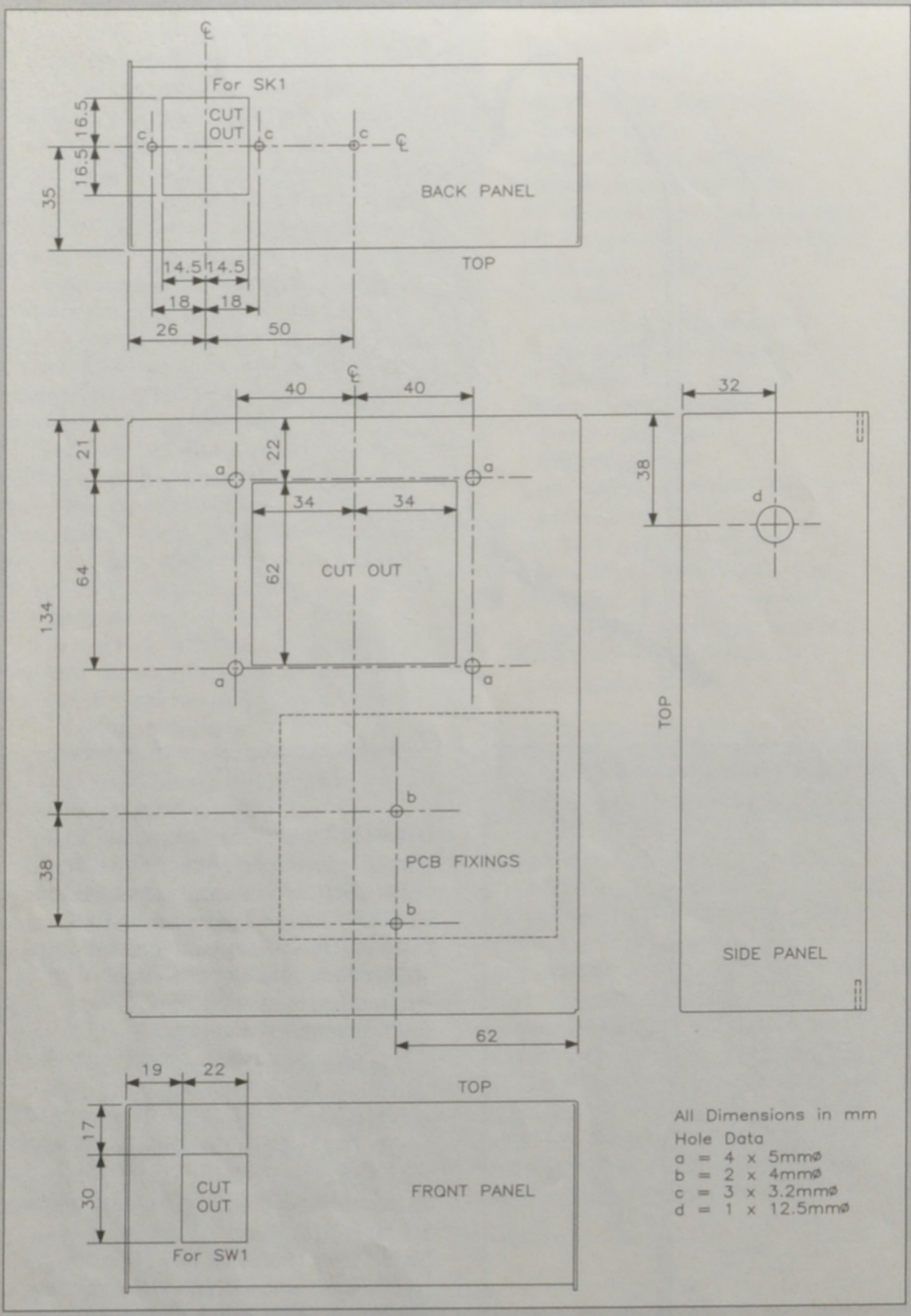


Figure 7a. Chassis drilling details.

on the PCB legend! Next install the fuseholder clips for FS2, followed by C6.

Prepare and fit the 68µF 500V can electrolytic C1, as graphically shown in Figure 5. First, attach and solder short lengths (about ½in.) of stranded black hook-up wire to the two M4 solder tags supplied with the kit hardware, before fixing the tags to the threaded terminals of the capacitor. WARNING: the polarity of this capacitor is not clear; the (+) terminal is only identified by a tiny (+) symbol embossed on the black insulator material adjacent to the actual plus terminal itself, DON'T get them confused! The (+) terminal must correspond to (+) on the PCB legend when C1 is strapped in place.

Attach the solder tags to the threaded terminals of C1 using the M4 hardware supplied with the capacitor. Place the shakeproof washer *underneath* the tag washer; this prevents the tag washer twisting round when the fixing screw is tightened. Both tags must point down toward the PCB, where the (+) terminal is towards the centre of the PCB.

Trim and strip the hook-up wires to reach and pass through the (+) and (–) PCB holes when you lay C1 in position on the board. It is held in position by two 140mm tiewraps used in combination; that for the top loop is inserted fully through one of the holes provided in the PCB up to its catch from the track side, looped over C1 and then down through the hole on the other side. The lower tiewrap is then used to secure these two ends underneath.

Solder and trim the hook-up wires to their solder pads on the track side of the PCB. You may now insert 1¼in. fuse FS2 (250mA anti-surge type).

Lastly, fix the 3-way screw terminal block in position at TB1 as shown in Figure 6 using the two long M3 screws, nuts and shakeproof washers. DO NOT overtighten or the block will be distorted. Connect a short length (approx. 1¼in.) of black 3202 wire between the larger common OVE pin (P1) and the *central* screw terminal of the block, on the side facing in toward the centre of the board.

Double-check the PCB for the quality of solder joints and correct orientation of components. Once the PCB is installed in the chassis it will be quite awkward to remove again to correct errors! Using an ohmmeter, check again the correct polarity of all four rectifiers D1 to D4 – there should be the same high resistance registered on the meter scale when the probes are applied to the 'IN 350V' input pins P4, P5 either way round, which will increase to approximately 470 to 500kΩ and stop once C1 has charged. If this is not the case, trace and rectify the problem now.

The PCB includes a solder resist on the track side. After removing flux with a PCB cleaner, track side solder joints should be covered with a conformal coating to help the solder resist prevent creepage, or tracking, between points of high potential difference. Some areas are at the full HT line potential (up to 500V DC), specifically in the areas occupied by D1 to D4, C1 and FS2.

Preparing the Chassis

Cutting and drilling details are given in Figure 7a and b. All holes are made in the *main body* of the 8 x 6in. aluminium chassis; the removable lid will become the *bottom*, not the top! In summary these are:

Top panel: rectangular cut-out for T1 solder-tag side with four 5mm dia. bolt holes, plus two 4mm dia. holes for M4 PCB support pillar screws in the positions indicated.

Front panel: neon rocker switch SW1.

Rear panel: fused euro mains inlet socket.

Right-hand side panel: cable loom access hole near rear end (½in. dia.).

The transformer T1 is designed along the traditional style for valve transformers in general, and its main feature is the method of mounting. T1 is actually mounted *on top* of the chassis, and is *not* enclosed inside it. For this reason it has a steel top cover to shield the internal former and comply with safety requirements. The other side of the former possesses all the connection points, and this is inserted fully into the interior of the chassis and is out of harm's way in use.

Important note: due to the heavy gauge of the heater windings,

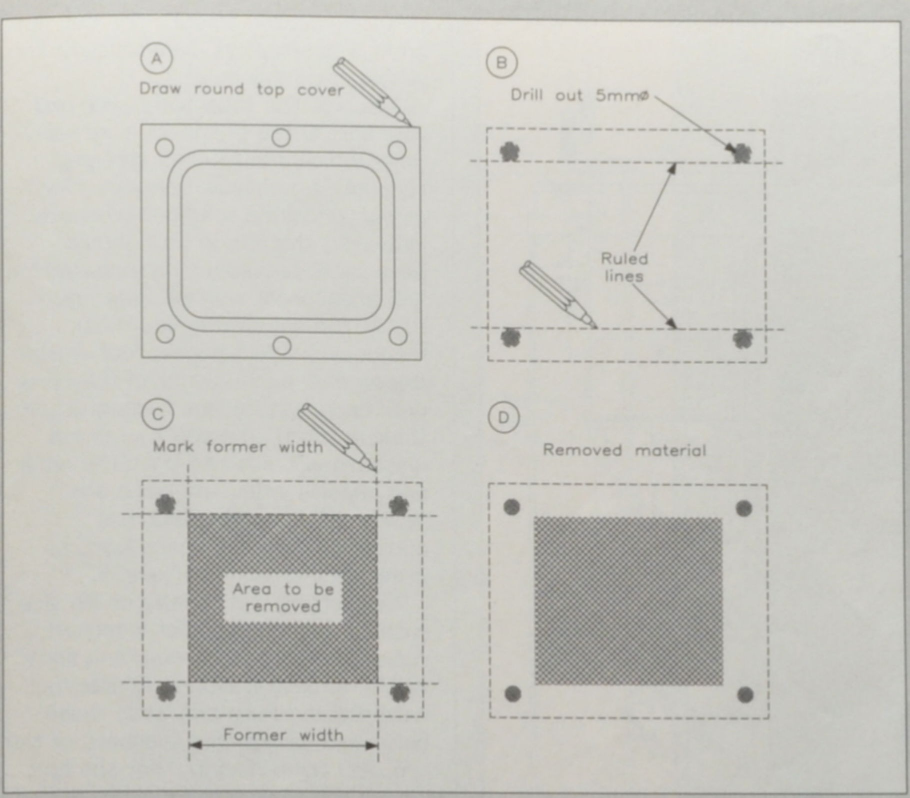


Figure 7b. Alternative method for making the cut-out for the transformer.

these are *not* terminated with conventional solder-tags. Instead the actual copper wire is brought out and sleeved for direct connection. Although strong, avoid bending them about more than is absolutely necessary.

It can be rather awkward making the cut-out and drilling for T1, but I've found one good trick is to proceed as shown in the sequence Figure 7b. Remove all four bolts from the transformer and remove the top cover. Using the cover as a template, position it on the chassis top according to Figure 7a, and draw round it with an indelible felt-tipped marker (such as a fine tipped PCB pen) to trace the rectangular outline. Then mark the four corner bolt holes by ringing them round inside with the pen. On removal of the cover the four bolt holes will be marked exactly, as the first stage in Figure 7b. Do not reassemble the transformer yet.

Drill the four holes out to 5mm diameter. Now comes the tricky bit, but ingenuity is to the rescue. Using a steel rule and the indelible marker, draw two lines between each pair of holes that share the *longest side of* the rectangle in each case, such that each line touches the edges of both holes on the *inside* of the rectangle.

Stand the core of T1 up on its longest side on the chassis top such that two bolt holes align with two of your drilled holes. Looking vertically down the edges of the former you can now mark where the ends of the former will be and draw two lines ACROSS the rectangle, intersecting the first two lines. You should now have an inner rectangle which, when cut out as in the last part of Figure 7b, is in area equal to the space required for the T1 former, complete with solder-tags, etc., to pass through, but which does not encroach on any of the bolt holes (important to maintain strength in the chassis).

If you are going to use a nibbling tool to cut the rectangle, you cannot operate it from inside the box due to an acute lack of manoeuvring space. In this case, drill a small hole (e.g., 1/16in.) at each corner of the inner rectangle from the outside, turn the chassis over and join these holes using a short straight edge and the marker pen on the inside surface. After making a hole big enough for the nibbler you can then trace its course by following the lines on the inside.

Don't forget also the rear mains inlet and front panel switch cut-outs (Figure 7a). The same trick can be used for these. Also, to the rear of the right side of the chassis, a 1/2in. dia. hole is needed for cable exits to adjoining chassis. This then has the 9·5mm grommet inserted. An adjoining chassis will have to have a corresponding 3/4in. (15mm) dia. hole to clear the outer diameter of the grommet when it butted up to the PSU chassis.

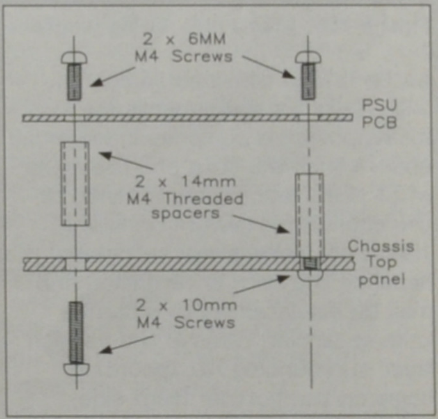


Figure 9. Mounting the PSU PCB.

Assembling The Chassis

With all holes prepared, begin by mounting T1 with reference to Figure 8 (the sooner you get used to man-handling this lump the

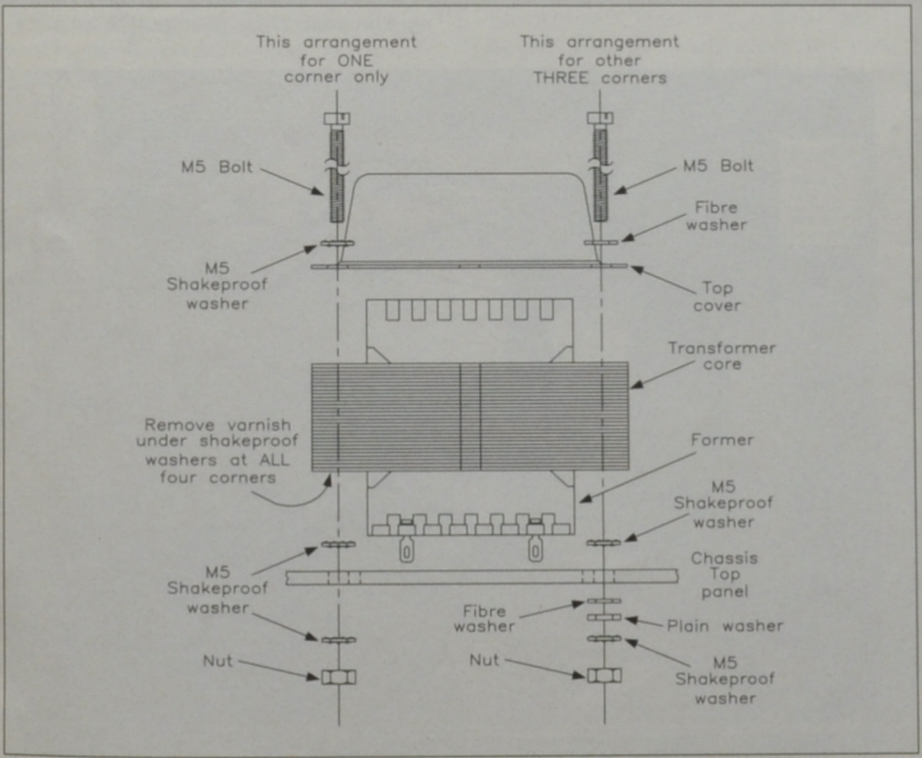


Figure 8. Mounting the transformer T1.

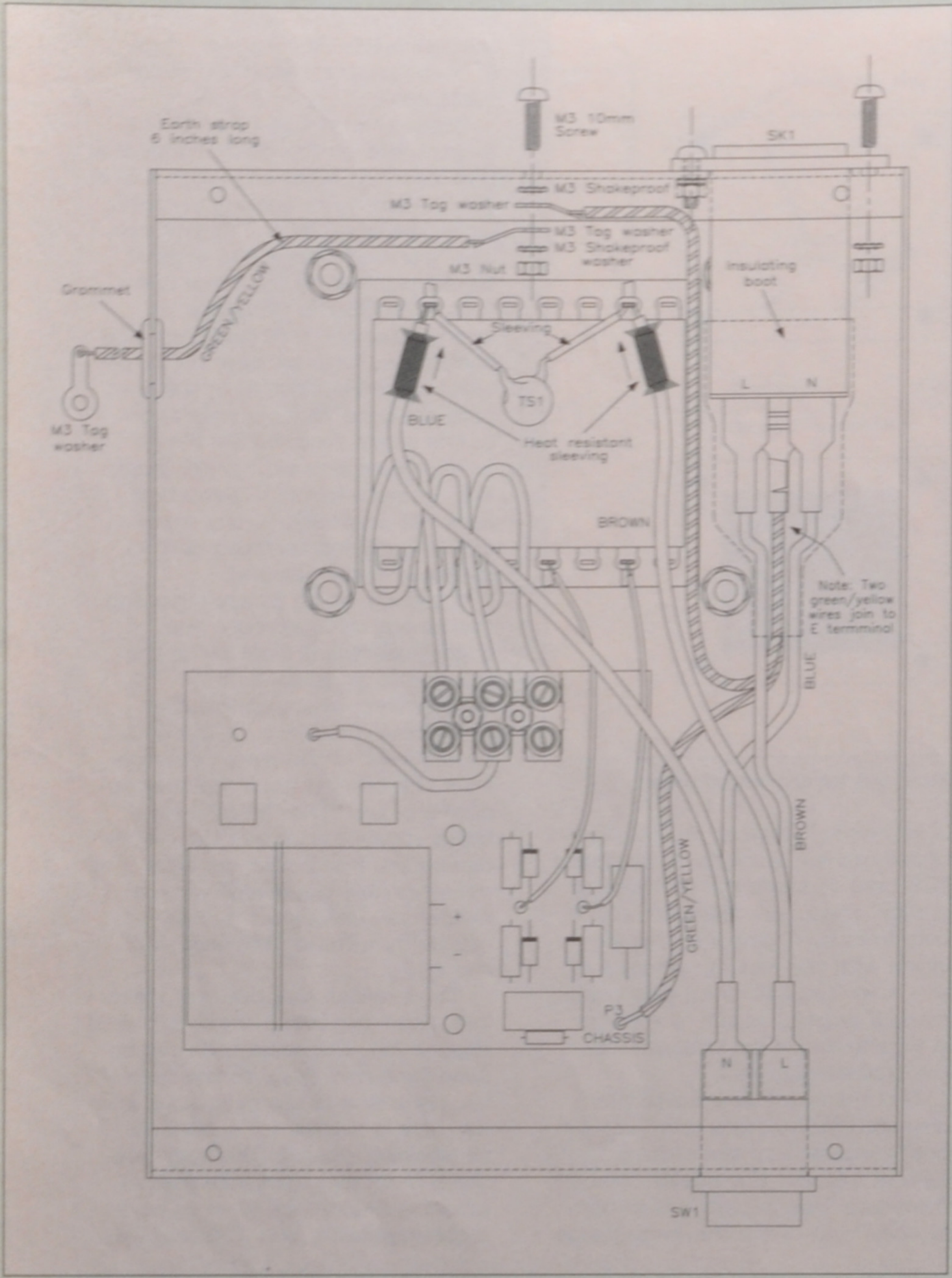


Figure 10a. Mains side wiring diagram.

better). First of all, to comply with Class 1 requirements for mains powered equipment, we must ensure that the core and top cover of T1 are satisfactorily earthed to the chassis metalwork on fitting. This is not necessarily automatic because the core is varnished and may be insulated. With a strong knife or similar, remove the varnish layer surrounding ALL mounting holes on the bottom (tag) side.

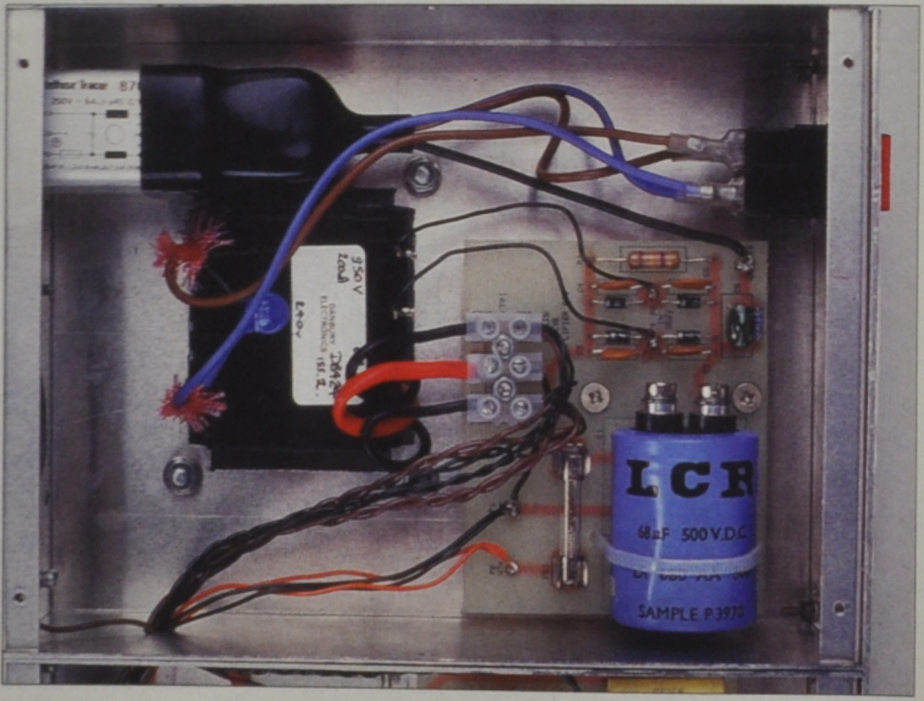
With T1 upside-down on the bench (solder-tags uppermost), *gently* manoeuvre the chassis over the solder-tags, heater wires and former until it seats on the core. The mains input connections must be toward the rear, and the HT secondary and heater wires must be toward the front panel. This method is preferable to trying to insert T1 into the chassis from above, which will certainly break an exposed fine wire or two if it slips. With it properly seated (modify the cut-out to fit if necessary), *carefully* turn the whole assembly over.

Replace the steel top cover and re-insert three of the four corner bolts which should drop straight through the chassis beneath. *Don't forget* to include the fibre washers! However, the fourth bolt should have its fibre washer *replaced* with a M5 shakeproof washer (see Figure 8). At the same time you must manoeuvre a M5 shakeproof washer *underneath* each corner of the core until each bolt passes through them (four in total). The teeth of these washers will bite into both the core and chassis when the bolts are tightened, ensuring electrical continuity between these two, as graphically shown in Figure 8.

Supporting the chassis on its side with T1 in situ (don't let it move!), replace three of the remaining fibre washers, plain washers, shakeproof washers and nuts *only* onto those bolts also having fibre washers at the top, and tighten lightly. For the bolt having the shakeproof washer at the top, only replace its M5 shakeproof washer and nut, excluding the plain and fibre washers. By having shakeproof washers at top and bottom, this bolt will ensure that the top cover is electrically connected to the chassis also.

Using a screwdriver above and a 2BA or equivalent spanner beneath, tighten all four bolts evenly a bit at a time, swapping diagonally. Do not overtighten or the fibre washers may be destroyed. These are important for those bolts that have them, as they help prevent each attempting to behave as a shorted, single-turn winding as they pass through the core.

This done, install the mains rocker switch by pressing it into its



Inside view of the PSU chassis showing wiring.

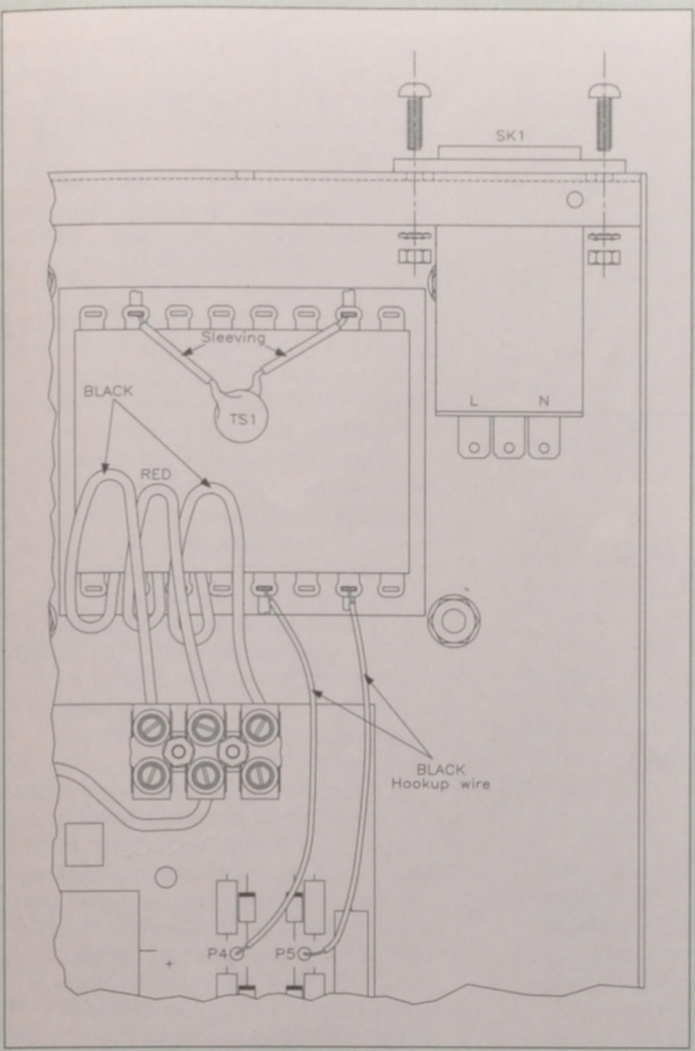
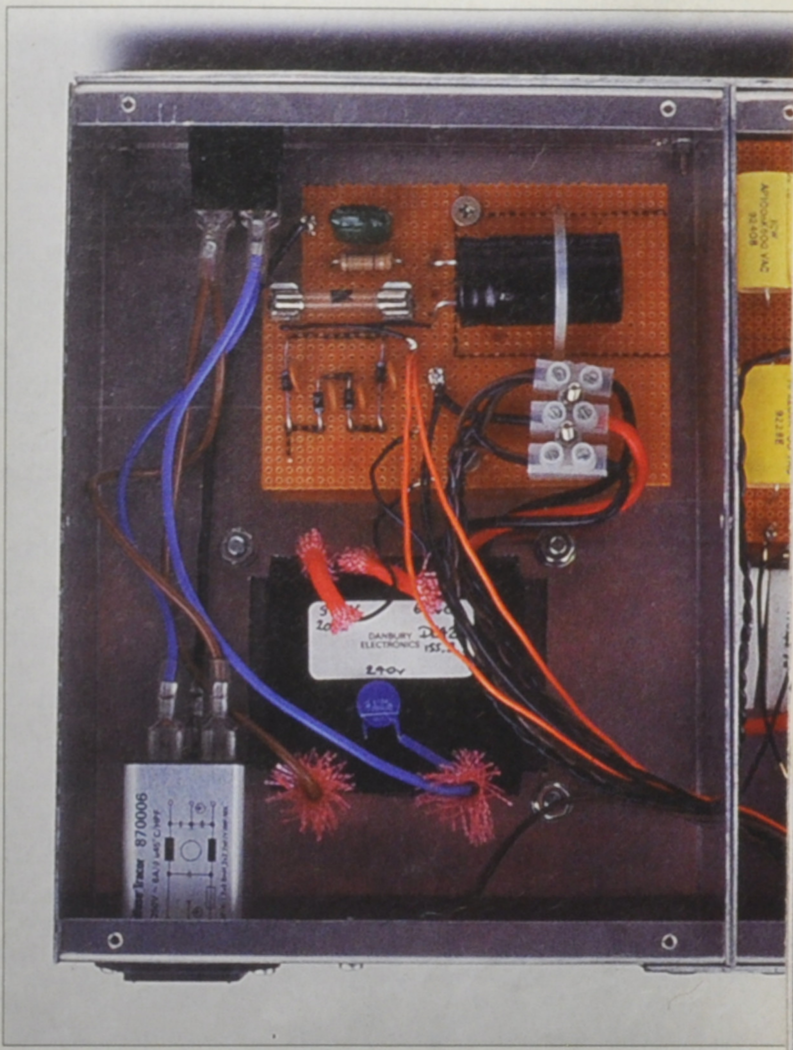


Figure 10b. Secondary side wiring diagram.



Inside view of the prototype PSU chassis.

rectangular cut-out (all terminals orientated toward what will be the *top* of the chassis) then the fused euro mains inlet socket at the rear (fuse tray toward what will be the *bottom* of the chassis). The body will automatically make an earth connection with the chassis when secured in place with two M3 x 10mm bolts, shakeproof washers and nuts. If you are going to paint the chassis first, make sure to leave bare metal around the vicinity of this socket's fixing points, or mains earth may be isolated from the chassis by the paint!

Finally, mount the two M4 x 14mm threaded spacers to the inside of the chassis if not already in place, using the two M4 x 10mm screws through the top panel, see Figure 9.

Mains Wiring

Complete the mains side wiring with reference to Figure 10a. Prepare two 7cm lengths of green/yellow 6A wire with one ¼in. push-on connector crimped and soldered onto two stripped ends (no insulating sleeve required), and push the connector onto the ¼in. earth terminal of SK1. One wire connects to the PCB (see next section), the other connects to an M3 solder tag which bolts to the case.

Prepare one blue and one brown 8cm lengths of 6A wire with insulated ¼in. push-on connectors at each end, and include the insulating boot for SK1. Prepare a further blue and brown pair 11cm long, with insulated connectors at one end of each only.

Referring to Figure 10a, connect together the Live and Neutral terminals of the euro mains inlet socket SK1 with the *lower* (as you see them now) Live and Neutral terminals of the rocker switch SW1 (not the *central* pair), with the Brown and Blue 8cm leads. Also push the black earth lead from the earth terminal of SK1 through the boot, and cover all connections of SK1 with the boot. The boot should be stretched over the rear end of the metal body of SK1, and will need persuading with a thin bladed screwdriver or similar, and perhaps a little lubricant. (It may be a good idea to press the boot onto SK1 as soon as you receive the kit to 'train' it into the right shape before final assembly.) Likewise connect the 11cm Brown and Blue leads to the *central* terminals of SW1. After slipping on 1 inch lengths of heat resistant sleeving, strip and solder the other ends of these leads to the 240V mains primary solder-tags of T1; trim lengths to suit. To fit the transient suppressor, sleeve its leads with offcuts from 6A wire and connect directly between the primary solder-tags of T1. Cover both tags with the heat resistant sleeving.

Finally install the 1A fuse FS1 into the fuseholder tray of SK1 (the tray is released by squeezing the clips at either side). If the PSU is going to be physically joined to further chassis (which is almost certain), you will need to make up an earthing strap from the remaining green/yellow 6A wire with a M3 solder tag at each end. Upon two chassis being bolted together, the earthing strap must connect both electrically by being attached to each via dedicated fixings, using M3 x 10mm bolts, shakeproof washers and nuts at each tag washer. The M3 hole adjacent to SK1 position on the rear panel (Figure 7a) is for this purpose.

Wiring Up The PCB

With the chassis upside down and the front panel facing you, the PCB is mounted onto the two 14mm pillars with the terminal block nearest T1 (i.e. uppermost). Fix in place with two M4 x 6mm screws into the pillars, see also Figure 9. The positions of these pillars in the chassis as shown equate with the positions of the mountings of the amplifier PCB for neatness; you may move them if you wish.

Refer to Figure 10b for the secondary side wiring. Before you do anything else, now is a good time to connect up the heater wires from T1, which all go to the top side of the 3-way screw terminal block TB1. First solder together the red sleeved centre tap pair. Beginning with one of the black sleeved single wires, manipulate all three to insert and secure them into the top side of the terminal block such that the red sleeved pair is in the middle (and connected to the 'OVE' pin P1 on the PCB), and the black ones are at the outermost ends of the block. These wires are *extremely* stiff and you will need long-nosed pliers and lots of patience! Screw down each fairly tightly in its terminal to ensure a good connection. Double-check with an ohmmeter that you have continuity (very low resistance) all the way through from one end to the other, and to the common 'OVE' pin P1 on the board.

Strip and wrap and solder the 6A green/yellow earth wire from SK1 to pin P3 marked 'CHASSIS'. Check with an ohmmeter for continuity between 'OVE' pin P1 and the chassis itself, it should be 100Ω. The function of the 100Ω resistor R2 is to block any earth loop formed between chassis mains earth and circuit or signal earth ('OVE'), without the two completely losing contact for screening purposes. If internally wired up properly as described, it is possible to connect the amplifier(s) with PSU physically attached to a mains earthed signal source with a screened lead, with continuous screening on both cables if stereo, commoned at the source end by the source's common earth without creating an audible hum loop.

Using the black hook-up wire, wrap and solder two lengths between the 'IN 350V' pins P4 and P5 and the 350V secondary tags of T1, and sleeve the tags with heat resistant sleeving. This completes the construction of the Power Supply Unit.

Testing The PSU

With the chassis still upside down and the bottom cover off, plug a euro mains lead into SK1, switch on at the mains socket and switch on the front panel rocker SW1. The red neon lamp should light and the transformer may be heard to hum slightly (the chassis might even feel 'tingly' to touch, but don't worry, it's only vibration!).

Set a multimeter to its highest (e.g., 500 to 1000V) AC range, and with insulated probes check for 350V AC (approximately) at T1 secondary output pins P4, P5 on the PCB ('IN 350V'). Remove probes. Switch to 10V AC range or equivalent, and check heater supply output across the terminal block. It should be 6·3V between both black leads, and 3·15V between either and the common earth 'OVE' P1 on the PCB.

Switch to a high DC volts range (500 to 1000V), and test the main line HT output against 'OVE' (black probe to P1, red probe to P2). It will very likely be quite high at nearly 500V DC or so. In actual use, with amplifiers connected, the HT level is reduced, due to internal winding resistance in the T1 HT secondary, to <450V. Remove probes.

Switch off at the front panel. Stand by with the multimeter probes and re-check the HT level. It should be falling; this proves that the safety discharge resistor R1 is working. If you need to sort out a problem, carry out the complete SIDE procedure BEFORE TOUCHING ANYTHING! It will take nearly a minute for the HT to completely discharge, in the absence of any other load.

If all is well after the above tests, switch off at the mains socket and remove the mains lead. Apply both the Mains Warning and High Voltage Warning Labels to the bottom cover, and temporarily fit it to the chassis with four of the self-tap screws provided, until you need to open it again to connect up an amplifier, which will be next month.

VALVE AMPLIFIER PSU PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1	470k 1W	1	(C470K)
R2	100Ω	1	(M100R)
CAPACITORS			
C1	68µF 500V Can Electrolytic	1	(DM57M)
C2-5	10nF 1000V Disc Ceramic	4	(JL04E)
C6	220nF Mylar	1	(WW83E)
SEMICONDUCTORS			
D1-4	1N4006	4	(QL78K)
MISCELLANEOUS			
	Aluminium Chassis AC86	1	(XB68Y)
T1	Valve Amp Mains Transformer	1	(DM54J)
SK1	Fused Mains Inlet/Filter	1	(KR99H)
	Insulating Cover for above	1	(JK67X)
FS1	F1A 20mm Fuse	1	(WR03D)
TS1	250V AC Transient Suppressor	1	(HW13P)
FH1,2	1¼in. Fuse Clip	2	(KU28F)
FS2	T250mA 1¼in. Fuse	1	(UK00A)
TB1	5A Terminal Block 12-Way	1 Strip	(HF01B)
	Black Hook-Up Wire	1 Pkt	(FA26D)
	Red Heat-Resistant Sleeving	1m	(BL70M)
	1mm PCB Pin	1 Pkt	(FL24B)
	1·3mm PCB Pin	1 Pkt	(FL21X)
	Push-On ¼in. Connector	1 Pkt	(HF10L)
	Push-On ¼in. Covers	1 Pkt	(FE65V)
	9·5mm Grommet	1 Pkt	(JX63T)
	Green/Yellow 6A Wire	1m	(XR38R)
	Brown 6A Wire	1m	(XR34M)
	Blue 6A Wire	1m	(XR33L)
	M4 Threaded Spacer	1 Pkt	(FG39N)
	M4 x 10mm Steel Bolt	1 Pkt	(JY14Q)
	M4 x 6mm Steel Bolt	1 Pkt	(JY13P)
	M4 Solder Tag	1 Pkt	(LR63T)
	M3 x 20mm Steel Bolt	1 Pkt	(JY25C)
	M3 x 10mm Steel Bolt	1 Pkt	(JY22Y)
	M3 Steel Nut	1 Pkt	(JD61R)
	M5 Shakeproof Washer	1 Pkt	(BF42V)
	M3 Shakeproof Washer	1 Pkt	(BF44X)
	M3 Solder Tag	1 Pkt	(LR64U)
	140mm Long Tie-Wrap	2	(BF92A)
SW1	DPST Red Neon Rocker Switch	1	(YR70M)
	Mains Warning Label	1	(WH48C)
	High Voltage Warning Label	1	(DM55K)
	PCB	1	(GH59P)
	Instruction Leaflet	1	(XU45Y)
	Constructors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items are available as a kit, which offers a saving over buying the parts separately.

Order As LT44X (Valve Amplifier PSU Kit) Price £49.95 C6.

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1994 Maplin Catalogue.

Valve Amp PSU PCB **Order As GH59P Price £3.65.**

High Voltage Warning Label **Order As DM55K Price 95p.**

Valve Amp Mains Transformer **Order As DM54J Price £26.95 C5.**

68µF 500V Can Electrolytic **Order As DM57M Price £8.95.**

by Graham Dixey
C.Eng., M.I.E.E.

Part 3

POWER ELECTRONICS IN THEORY & PRACTICE

Rectification is the process of converting an alternating voltage into a unidirectional one. This may be performed by using a unilateral device such as a diode and, in the last article, we looked at a number of circuits that did just that. The DC output voltage depended primarily upon the value of the AC input voltage and upon the nature of the rectifier circuit i.e. half-wave or full-wave type. Apart from these considerations, there was no other control over the value of the output voltage. You can use a more sophisticated stabiliser section, after the basic transformer/rectifier stage, which would itself incorporate the required degree of control. The diode, by its very nature, always started to conduct when it had sufficient forward voltage, this being about 0·6V for silicon devices.

THE Silicon Controlled Rectifier, or SCR for short, is a four-layer diode with a third terminal, known as the 'gate'. This electrode allows the conduction point (in time) to be determined by the application of an external signal. Thus, the limitation that the device will always begin to conduct when the forward voltage across it reaches approximately 0·6V is lifted. Since the SCR only conducts when the gate conditions are right, and when the anode is positive with respect to the cathode, it follows that the SCR can also be used to rectify an AC input. Additionally, there is the added advantage that the output is fully controllable by governing the conduction point of each cycle of the alternating input.

In this article, we shall look at a number of rectifier circuits that make use of SCRs. However, before we do so, it is useful to look briefly at the use of the SCR in fields where rectification is not required but where the 'latching' property of the SCR can be usefully employed. These applications are usually found where the supply is DC.

THE SCR AS A LATCH

In Part One of this series, we discussed the basic principles of operation of the SCR. We found, for example, that it was possible to make the SCR go from a DC blocking condition to one of conduction, by supplying the correct combination of forward voltage and gate current. For a given forward voltage, a particular value of gate current will cause the device to switch from the non-conducting to the conducting state. The lower the forward voltage across the SCR, the more gate current is required, and vice versa. If the forward voltage between anode and cathode is high enough, the SCR will conduct even when the gate current is zero. There are various ways of supplying the gate current and Figure 1 shows a circuit embodying what must be the simplest method.

In this circuit, the SCR is required to switch on a lamp. With the two switches, S1 & S2, in the conditions shown, the path for gate current is open. The DC supply on the anode of the SCR is insufficient on its own to cause the device to conduct. Only when switch S1 is closed does a path for gate current exist, through R1 into the SCR gate. The proportioning of the two resistors, R1 & R2, is such that sufficient gate current flows to cause the SCR to conduct. The lamp will then light. Switch S1 need only be a momentary push-button; releasing it will not cause the lamp to go out, even though doing so automatically interrupts the gate current. This is the 'latching' action referred to earlier. This action is inherent in the SCR and depends upon a certain 'holding current' flowing in the SCR between cathode and anode. This holding current is usually very small, certainly much less than the normal anode current in the load, so latching will always take place. The only way to switch the SCR off again is to reduce the anode current below the holding current value. The easiest way to do this is simply to interrupt the anode current momentarily. There is a finite time for which this interruption must be held, but manual operation of this type always ensures that this criterion is met.

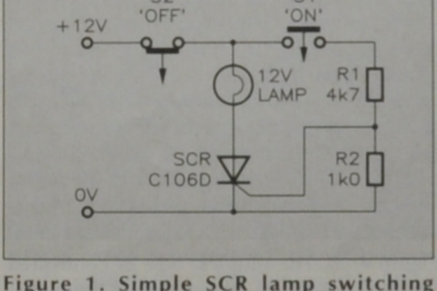


Figure 1. Simple SCR lamp switching circuit with manual commutation.

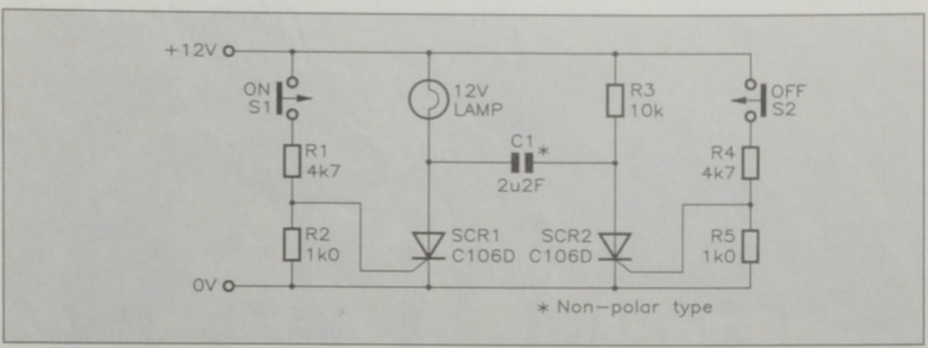


Figure 2. A lamp switching circuit using a second SCR and a commutating capacitor.

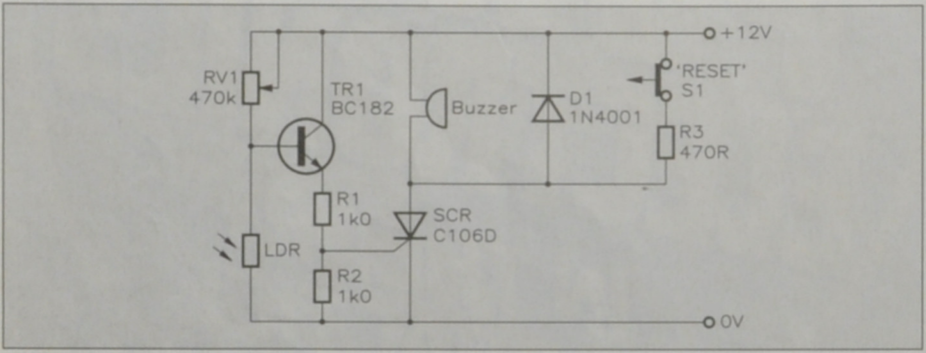


Figure 3. A light-operated alarm circuit.

COMMUTATION IN DC CIRCUITS

The process of turning off an SCR is termed *'commutation'* and in this circuit the process is carried out by the switch S2. This is obviously an easy way of doing it, but it does have a drawback as the 'OFF' switch has to be able to switch the full load current. This is not always convenient, especially with regard to the reliability of the switch contacts. Since semiconductor devices, including SCRs, are also capable of a switching action (and have the advantage of having no mechanical contacts), it is possible to have commutating circuits using a second SCR as the switching device. However, the commutating action is performed in a different manner, not by open-circuiting the current path through the SCR but by momentarily short-circuiting the conducting SCR, which has the same effect of robbing it of its current and so switching it off. A circuit that performs this action is shown in Figure 2, which makes use of a *commutating* capacitor. As a result of its action, the 'OFF' push-button switch no longer has to handle the load current which, in some cases, can be of the order of hundreds of amperes.

When power is first applied to the circuit, neither SCR is on.

Operating push-button S1 supplies the gate of SCR1 (the main SCR) with enough current to turn this SCR on and so energise the load. This now provides a charging path for C1 through R3 & SCR1. This capacitor, the so called commutating capacitor, rapidly charges up to the full value of the supply voltage, the right hand plate being positive. If now the push-button switch S2 is operated, the slave SCR (SCR2), turns on and its anode voltage falls to about +1V. Since there is a voltage of approximately 12V across C1, its left hand plate falls instantly to about –11V, thus reverse biasing SCR1 and turning it off – but, how is SCR2 itself switched off?

Once SCR1 is switched off, the only current path for the load is through C1 & SCR2. Naturally this can only be a momentary current path, as C1 charges up in the opposite direction. The previous situation has effectively reversed because, when SCR1 is next switched on, it will now commutate SCR2, so SCR2 will turn off. Therefore, the conduction effectively 'toggles' between the two SCRs. Since the polarity of the voltage across C1 reverses regularly, this cannot be a normal electrolytic but must be a non-polar component. The value of this capacitor is important. It must be large enough so that it can store enough charge to hold SCR1 off long enough for it to drop out of conduction. If the circuit fails to function, it may well be that the load current is too high for the value of commutating capacitor used. The greater the load current handled by SCR1, the greater must be the charge stored in C1 in order to interrupt it.

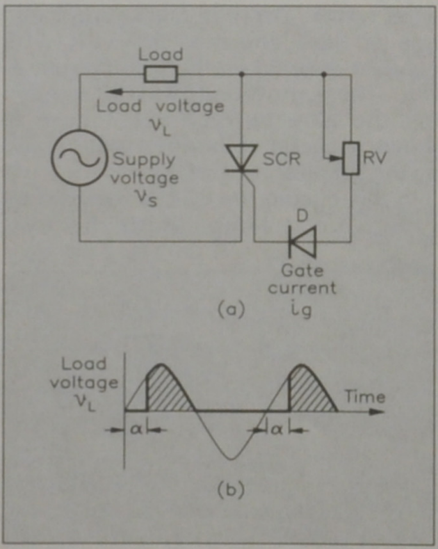


Figure 4: a), The simplest type of controlled rectifier circuit; b), waveforms of the load voltage for the above circuit.

A LIGHT-OPERATED ALARM CIRCUIT

Figure 3 illustrates one of many possible ways of switching on an SCR without the use of a mechanical switch.

In this circuit, an LDR is connected between the base of transistor TR1 and ground. This LDR is assumed to be illuminated from some light source so that its resistance is low. As a result, TR1 is cut off and the gate of the SCR is at 0V, so that this device is also cut off. If now, the light beam falling on the LDR is momentarily interrupted, the LDR's resistance will briefly go high, TR1 will turn on momentarily and a voltage pulse (whose duration is equal to that of the interruption) will be applied to the gate of the SCR, turning it on and energising the buzzer. Of course, the SCR will be latched on until the 'reset' push-button switch is operated. The reason that this switch is able to perform the commutating action at all may not be obvious. However, it has to be appreciated that the buzzer comprises an oscillating contact, which means that the anode current comprises two components – a high frequency intermittent current through the buzzer, and a steady current through the S1 & R3 path. Remove the steady current, as happens when S1 is operated, and the SCR stops conducting.

CONTROLLED RECTIFICATION

Now we come to some circuits that make use of the particular properties of the SCR for obtaining controlled rectification. Before examining any of these, we must consider the matter of commutation in circuits that operate from AC supplies. Is this going to be a problem? The answer is, no, because AC circuits are, by their very nature, self-commutating. This sounds very clever but it is not really. We know that in order to perform commutation we have to interrupt the anode current, or force the anode voltage to become zero.

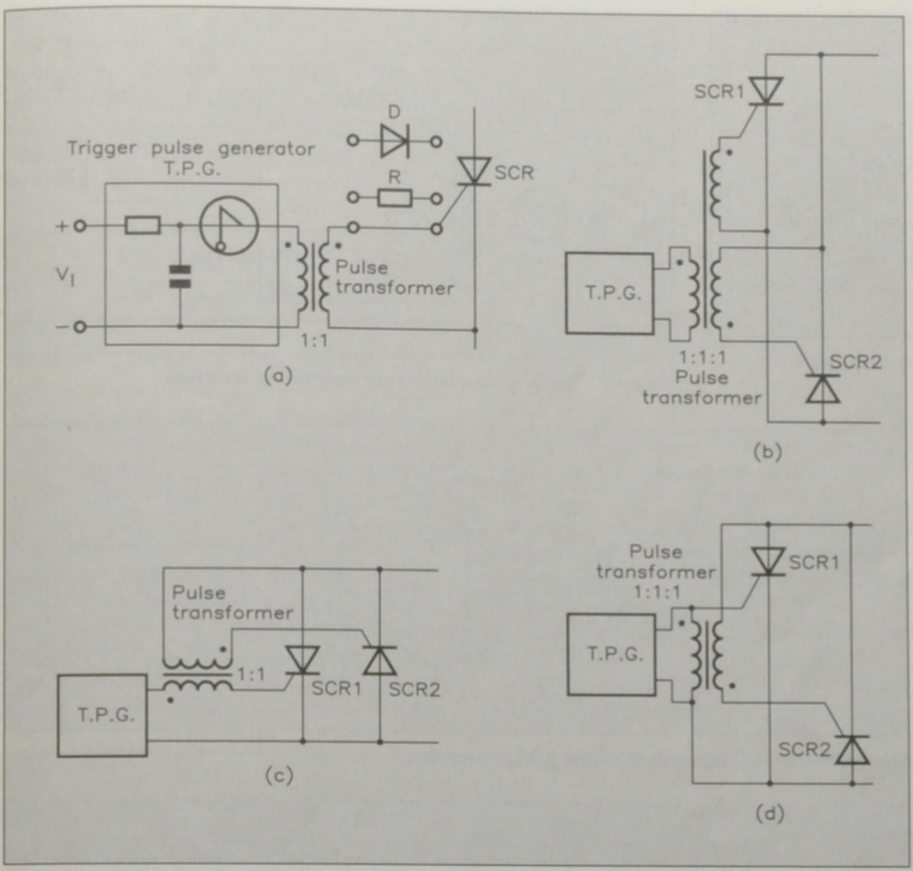


Figure 5. Four circuits using a trigger pulse generator and pulse transformer.

Well, this is what happens automatically at the end of every half-cycle of an AC voltage, e.g., as we pass from the positive half-cycle to the negative half-cycle. Thus, the SCR will drop out at this 'crossing point' between half-cycles. Therefore, commutation is something that we can take for granted in AC controlled rectification.

Figure 4a shows a crude and simple means of controlling rectification in a half-wave circuit. The value of the gate current determines the point in time at which the SCR starts conducting. This is because of the interdependence of anode voltage and gate current mentioned earlier, and the fact that the anode current is rising from the beginning of the cycle onwards. As we decrease the value of RV, the switching point occurs earlier in time. This position from the beginning of the half-cycle to the 'firing point' is referred to as the 'firing delay', angle α, and is often called the *'firing angle'*. This angle is seen on the waveform diagram of Figure 4b. The shaded area of each rectified half cycle illustrates the load waveform and represents how much power is being supplied to the load. By controlling the angle α, we are controlling the shaded area and, therefore the load power.

Controlling the turn-on point in this simple way is no good for many applications as the actual firing point is neither sufficiently predictable nor repeatable. The SCR needs to be given a *short, sharp jab* at a precise instant in time, in order to obtain accurate control of load power. One way of doing this is to trigger it with short, timed pulses and a number of circuits using a simple pulse generator, see Figure 5.

THE TRIGGER PULSE GENERATOR AND PULSE TRANSFORMER

This Trigger Pulse Generator (TPG) comprises an RC time constant and a SUS (Silicon Unilateral Switch) type of thyristor, fed from a DC supply V1. The SUS triggers when the voltage across C reaches a particular value and generates a short sharp pulse. Pulses are not usually applied directly to the gate of the SCR but via a specially designed transformer, known as a *'pulse transformer'*, which provides isolation between trigger and power circuits. These transformers may have either a 1:1 ratio as used in the circuits Figure 5a, 5b and 5d, or a 1:1:1 ratio as used in circuit Figure 5c. In Figure 5a, the transformer secondary winding may either be connected directly to the gate of the SCR or via either a resistor or a diode. When a resistor is used, it either reduces the holding current of the SCR or it is used to balance the gate currents in circuits where two SCRs are driven. A diode will prevent reverse gate current due to ringing or reversal of the pulse transformer output voltage and additionally, will reduce the holding current.

The circuit of Figure 5b shows two SCRs being driven alternately from a three-winding pulse transformer (1:1:1). The phasing of the secondary windings is important to ensure correct operation.

In the circuits of Figures 5c and 5d, two SCRs are also being driven alternately, but using only a two-winding transformer. This works because one SCR is driven from the primary side, while the other is driven from the secondary side. However, full isolation is lost with this connection. The essential difference between the two circuits is that in Figure 5c the SCRs are series connected with the transformer, whereas in Figure 5d they are in parallel with the transformer.

SINGLE PHASE RECTIFICATION

In the circuit of Figure 6a the method of triggering is not specified, but is represented by a block. We can assume that some suitable method has been chosen and we can concentrate on the circuit principles. In many industrial applications, where controlled rectification is required, the load is not a pure resistance but may contain a substantial amount of inductance i.e. motors, switchgear and solenoids, etc. Therefore, when the load is cut off by the SCR being turned off, load current tends to continue flowing, the load voltage actually reversing at this time, which tends to return current to the rectifiers. If this is allowed to happen, they may not turn off as required. To ensure that they do, a commutating diode is wired across the load which reduces the load reverse voltage to the value of the diode forward volt drop and conducts the current away from the rectifiers; see Figure 6a.

A full set of waveforms is shown for this half-wave circuit in Figure 6b. V_S is the alternating supply voltage and a pulse of gate current i_g is applied α degrees after the start of the positive half-cycle. Up to this point the load voltage V_L is zero, but then rises abruptly to virtually the magnitude of V_S at this instant. Because of the inductive nature of the load, the load current i_L rises and falls exponentially during the remainder of the positive half-cycle and the whole of the negative half-cycle respectively. The current i_T through the SCR rises exponentially but falls abruptly at the crossing point due to the action of the commutating diode. The current through the latter, i_D, is complementary to the SCR current – note that the addition of i_T and i_D produces the current i_L, which is just what we would have expected. Finally, the voltage across the SCR itself, V_T, is complementary to the load voltage V_L – the addition of V_T and V_L produces the supply voltage V_S.

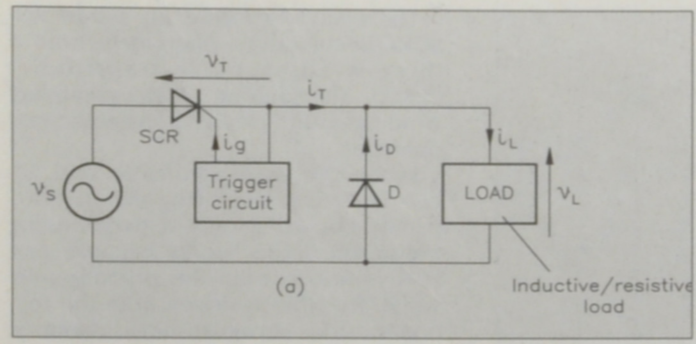


Figure 6a. Half-wave controlled rectifier with commutating capacitor and inductive load.

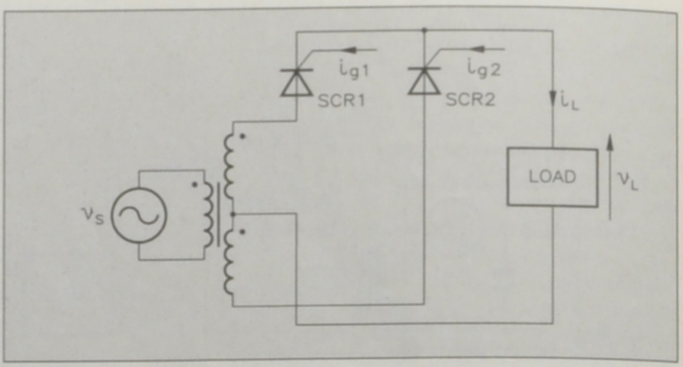


Figure 7. The bi-phase half-wave controlled rectifier.

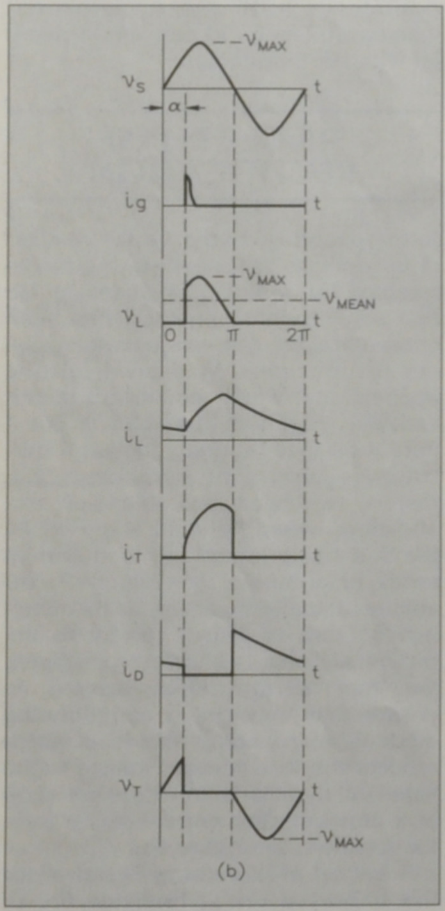


Figure 6b. Waveforms for the voltages and currents in the above circuit.

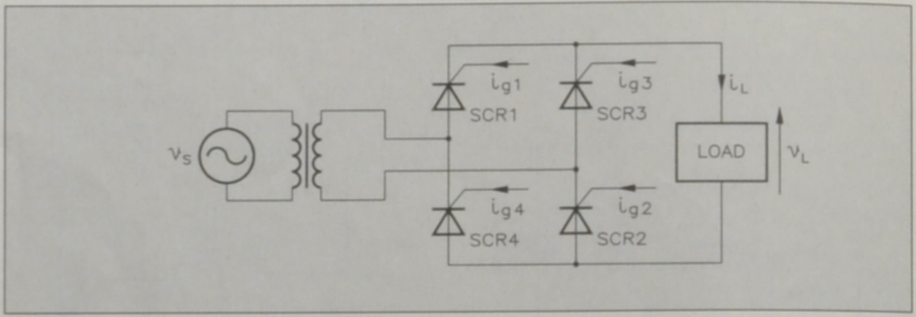


Figure 8. The SCR equivalent of the bridge rectifier.

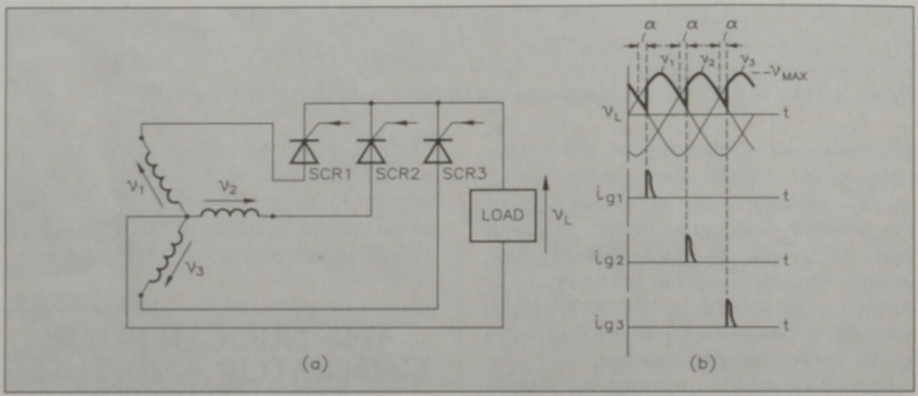


Figure 9. A three-phase half-wave rectifier.

Figure 7 shows another half-wave rectifier circuit, but one that is described as being 'bi-phase'. This term arises because of the centre-tapped transformer, from which are derived two anti-phase voltages – one for each of the two SCRs. These conduct alternately, supplying the load on both half-cycles. Therefore, the output voltage, pulsates at twice the supply frequency and it is possible to see a direct analogy between this and the equivalent diode circuit. The term 'half-wave' is perhaps rather misleading, since the output is actually full-wave, but is presumably derived from the fact that it comprises two half-wave rectifiers acting together. For this circuit, and those following, the actual details of the trigger circuits are not shown.

Figure 8 shows the SCR equivalent of the bridge rectifier, the operation being essentially the same, except for the fact that the conduction period for each pair of SCRs (SCR1 & SCR2 and SCR3 & SCR4 respectively) depends upon the triggering applied. This complicates the firing somewhat, since the SCRs must obviously be fired in the pairs mentioned above in order to conduct together.

In the last article several examples were given of polyphase rectifiers and, for consistency, Figures 9, 10 and 11 show some equivalent arrangements that use SCRs instead of diodes.

Figure 9 represents a three-phase half-wave system. The three phase voltages, shown on the circuit diagram and on the waveforms as v_1, v_2 and v_3, are 120° apart. The angle α is measured between the crossing point of consecutive waveforms and the firing point. The only other waveforms shown are the three gate current pulses i_{g1}, i_{g2} and i_{g3}. The full set of waveforms now become rather complex! The SCRs fire in sequence as the waveforms show and the effective DC output of the system is the average value of these waveforms.

Figure 10 shows a simple six-phase half-wave system in which the SCRs, SCR1 to SCR6, are fired in sequence. The higher the number of phases, the less is the variation in the output voltage. This means a higher value of effective output voltage, with a greater ripple frequency, which makes it easier to remove by subsequent filtering.

This point is emphasised by the full-wave bridge circuit of Figure 11. The star-delta transformer develops three phase voltages, V_a, V_b and V_c. These are applied to a bridge circuit comprising six SCRs connected across the load. The current paths are more complex than for the conventional four-diode bridge. For example, if the phase voltage v_a is at its peak value then, at this instant, both v_b and v_c will be negative. Consequently, current flow will take place through SCR1 and the load in series and will then divide into two to flow through *both* SCR2 & SCR6, the latter two SCRs taking equal currents. The waveforms show the three phase voltages referred to and the pulsating output, whose mean value almost equals the peak value of the line voltage.

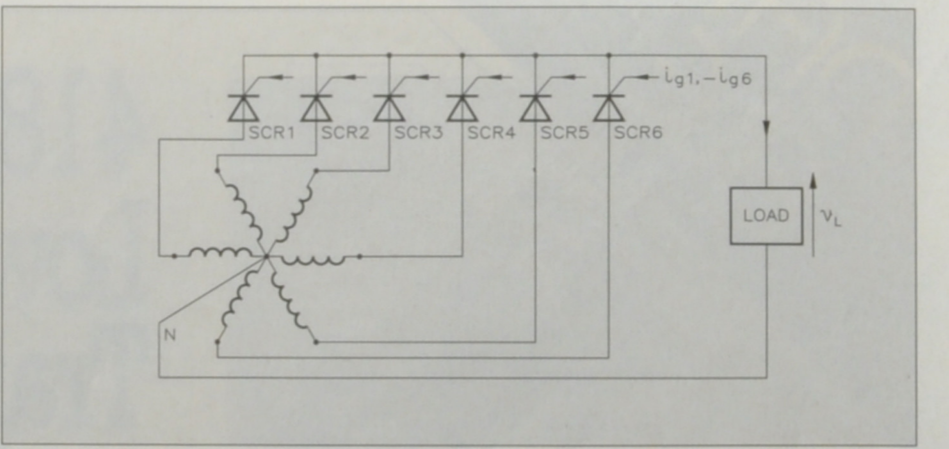


Figure 10. A six-phase half-wave rectifier.

PHASE SHIFT TRIGGERING

Another method of delaying the triggering point of an SCR is to introduce a phase shift between the alternating voltage supply applied between anode and cathode of the SCR and an AC supply applied to the gate. Because of this time delay, as well as the attenuation introduced by the phase shift network, the amplitude of the gate voltage is a lot smaller than the voltage on the anode of the SCR. By proper design, it is possible to achieve a point at which the gate voltage is just sufficient to cause triggering for a given anode voltage. By making the phase shift variable, usually by employing a variable resistor, it is possible to vary the relation between these two voltages and, thus, shift the triggering point along the time axis, one way or the other.

Figure 12 shows a single-phase bridge circuit which uses two SCRs as the controlled devices, in conjunction with two diodes, D1 & D2, to complete the bridge. The two identical resistors R_S limit the size of the gate currents and the phase-shift network comprises the variable resistor R_C and capacitor C. The following criteria can be used to design such a system, that is suitable for a wide range of SCR types.

a) The peak value of V_S (V_{Spk}) should exceed 25V.

b) $$\frac{1}{2\pi f C} = \frac{V_{Spk}}{2} - 9$$

c) $$R_s = \frac{V_{Spk} - 20}{0{\cdot}2}$$

d) $$R_c \geq \frac{10}{2\pi f C}$$

As an example, suppose that the secondary voltage V_C has an RMS value of 60V, this corresponds to a peak value equal to 60 x $\sqrt{2}$, which equals 85V. Assume that this is a 50Hz system then, from B, above, we have that:

$$\frac{1}{2\pi \times 50 \times C} = \frac{85}{2} - 9$$

$$\text{Therefore C} = \frac{10^6}{2\pi \times 50 \times 33{\cdot}5}\ \mu F = 95\mu F$$

$$\text{And } R_s = \frac{85 - 20}{0{\cdot}2} = 325\Omega$$

$$\text{Also } R_c \geq \frac{10}{2\pi \times 50 \times 95 \times 10^{-6}} \geq 335\Omega$$

This illustrates the ease with which the required component values can be calculated. In practice, the actual component values specified would probably be, in the order given above, 100μF, 330Ω and 390Ω.

That's all for this month; next time we will look at other triggering methods and certain safety aspects of SCR operation.

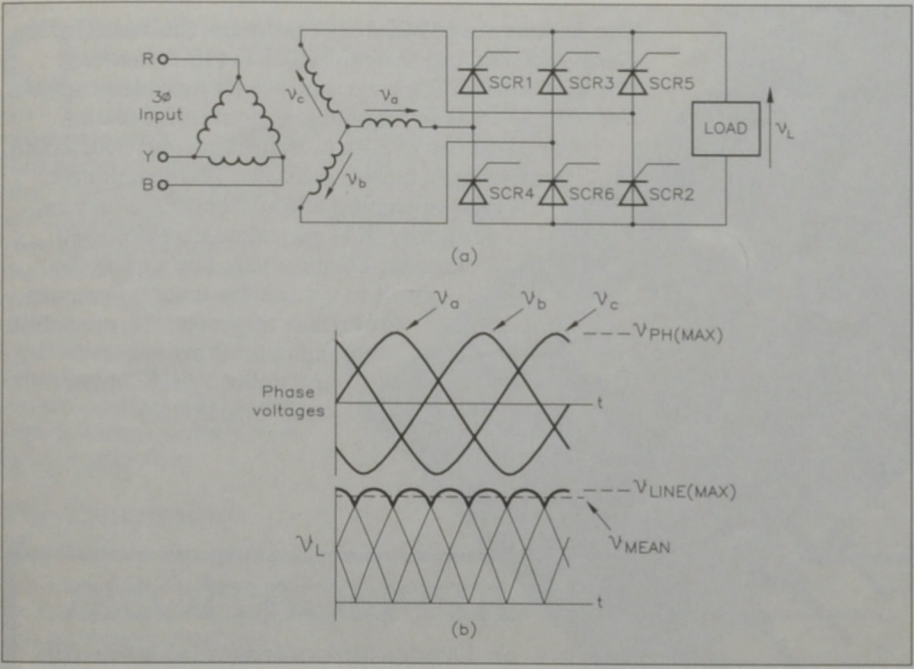


Figure 11. The three-phase full-wave bridge circuit.

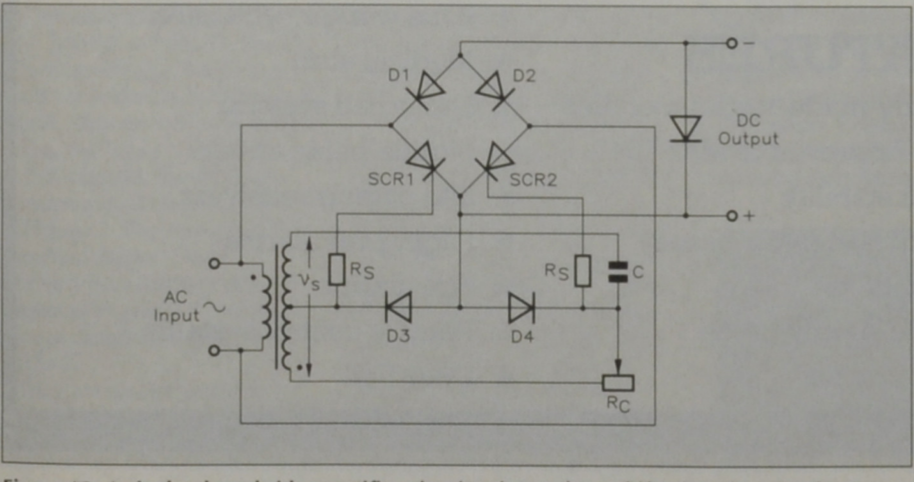


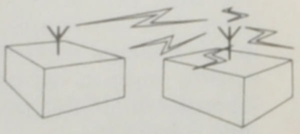
Figure 12. A single-phase bridge rectifier circuit using a phase-shift triggering circuit.

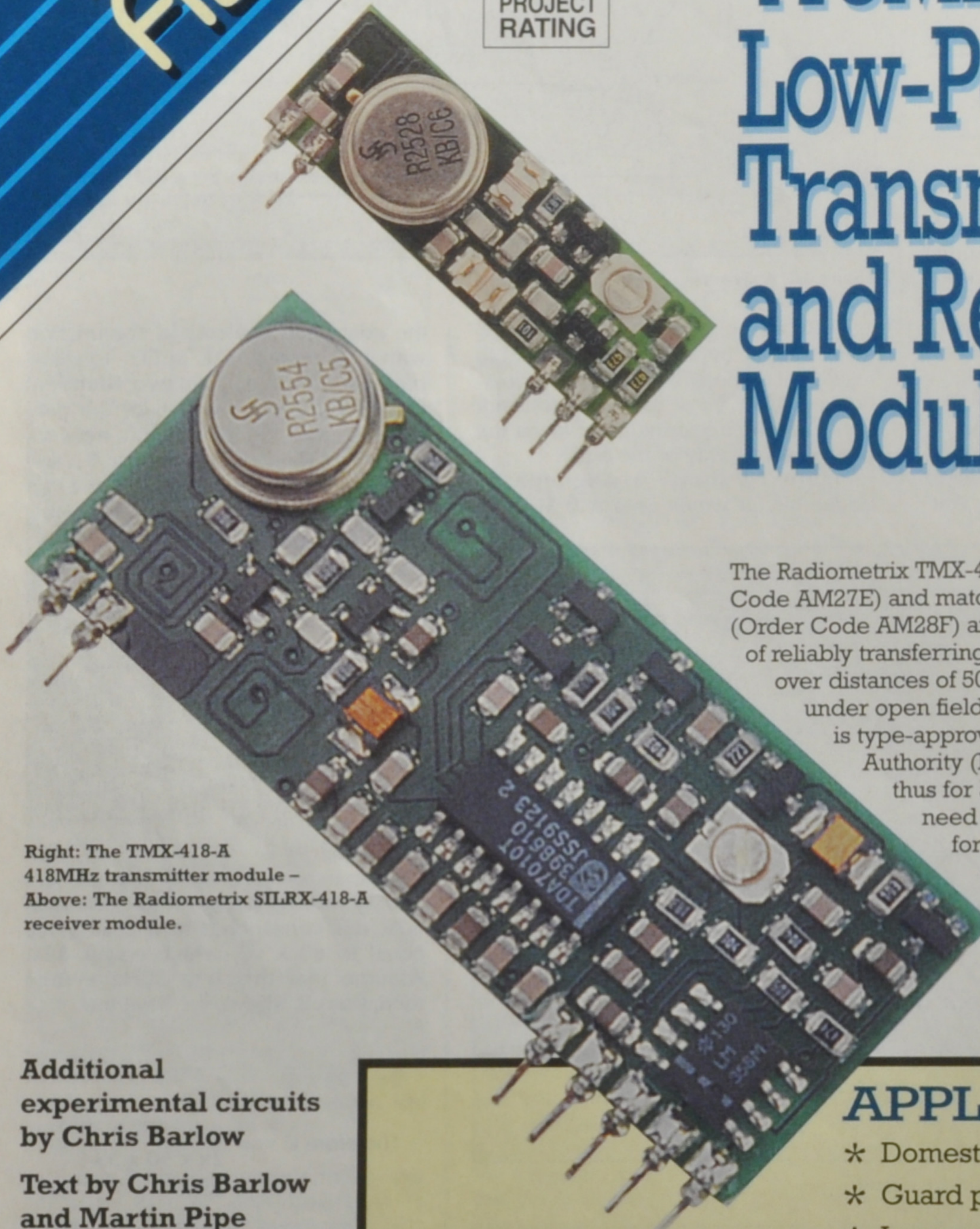
DATA FILE

'Data Files' are intended as 'building blocks' for constructors to experiment with and the components suggested, provide a good starting point for further development.

3 PROJECT RATING

418MHz Low-Power Transmitter and Receiver Modules





The Radiometrix TMX-418-A radio transmitter (Order Code AM27E) and matching SILRX-418-A receiver (Order Code AM28F) are ready-built modules capable of reliably transferring analogue and digital data over distances of 50m in buildings, and over 200m under open field conditions. The transmitter is type-approved to Radiocommunications Authority (RA) specification MPT 1340, thus for amateur use, this avoids the need to submit the finished project for further approval; the module's specifications are given in Tables 1 (transmitter) and 2 (receiver).

Right: The TMX-418-A 418MHz transmitter module – Above: The Radiometrix SILRX-418-A receiver module.

Additional experimental circuits by Chris Barlow

Text by Chris Barlow and Martin Pipe

FEATURES

- ✱ Ready-made/tested modules
- ✱ DTI Approved to MPT 1340
- ✱ High stability
- ✱ Small size (SMD-Based)
- ✱ Ease of use
- ✱ Wide supply range
- ✱ Low current

APPLICATIONS

- ✱ Domestic/commercial security
- ✱ Guard patrol protection
- ✱ Lone worker protection
- ✱ Medical alert
- ✱ Nurse call systems
- ✱ Mobile panic attack
- ✱ Site paging receivers
- ✱ Paging car alarms
- ✱ Fire alarms
- ✱ Remote control systems
- ✱ Door bell

Important Note:
Commercial use may require additional type-approval; in case of doubt contact the Radiocommunications Authority at the Department of Trade and Industry.

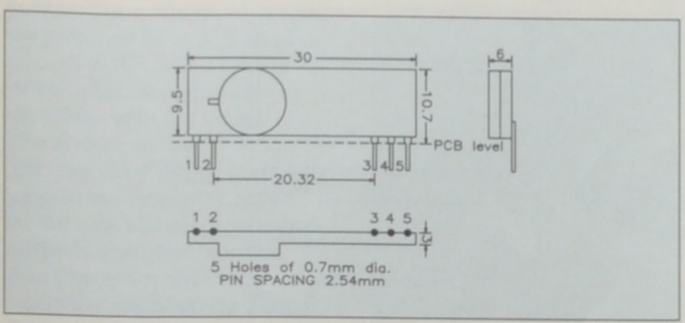


Figure 1. Physical dimensions of the Radiometrix TMX-418-A 418MHz transmitter module.

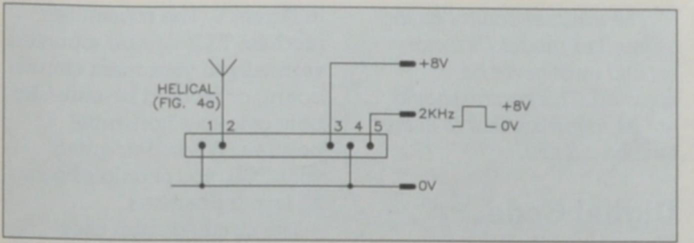


Figure 2. Transmitter test circuit.

Power supply voltage:	6 to 12V DC
Current consumption:	6mA (6V) to 14mA (12V)
Effective Radiated Power (ERP):	–10dBm (6V) to –6dBm (12V)
Initial frequency accuracy:	±50kHz
Overall frequency accuracy:	±80kHz
Spurious Radiation:	To MPT 1340
FM Deviation:	±25kHz
Modulation Bandwidth (analogue):	DC to 10kHz (–3dB)
Minimum pulse width (digital modulation):	100μs

Table 1. 418MHz transmitter specification (typical).

Operating supply range (V_{CC}):	4·5V to 9V DC
Supply current:	13mA
Overall frequency accuracy:	±100kHz
Sensitivity:	0·5μV for 20dB S/N
Carrier detector threshold:	1μV
RF input impedance:	50Ω
LO leakage:	–54dBm
IF bandwidth:	250kHz
AF output level:	500mV Pk-to-Pk
AF bandwidth:	DC to 5kHz (–3dB)
Frequency to voltage conversion:	10mV/kHz
Data output – logic low:	0·2V
Data output – logic high:	3·8V
Data bit duration:	0·2 to 30ms
Data mark/space ratio:	5% to 66%
Data settling time:	10ms
Enable time:	1·5ms
Signal detect time:	1ms

Table 2. 418MHz receiver specification (typical).

Optimised for battery-powered operation, both modules have been designed for reliability and performance in the field. They perform well with very small antennas, and require no complicated radio frequency (RF) alignment. The modules are suitable for general-purpose telemetry/telecommand, where their small size (they make extensive use of SMDs – surface mount devices) and high data rates (5kbit/s) may be of great benefit.

The Transmitter Module

The transmitter module requires only a power supply, data modulation input and an antenna. The module will operate over the range +6 to +12V DC and can be powered by, for example, 9V PP3 or 12V 'lighter' alkaline batteries. When operating, the device itself consumes a maximum of 20mA. This power is applied to the V_{CC} input pin (pin 3) of the module, the physical dimensions of which are given in Figure 1. The specifications shown in Table 1 were derived from the test circuit shown in Figure 2. Module pinout details are given in Table 3.

As you can see from the block diagram in Figure 3, the raw data is applied to pin 5 of the module. This is the input to a simple R/C low-pass filter (LPF), which restricts the modulation bandwidth to 10kHz at the –3dB point. The data input is normally driven directly by CMOS logic levels from a data encoder IC, such as the UM3750 (Order Code UK77J). The encoder is normally run from the same supply voltage as the transmitter module. Analogue drive – e.g., two-tone audio frequency shift keying (AFSK) – is also possible; note that the peak-to-peak level should be between 5 and 9V, and must not drive pin 5 below 0V.

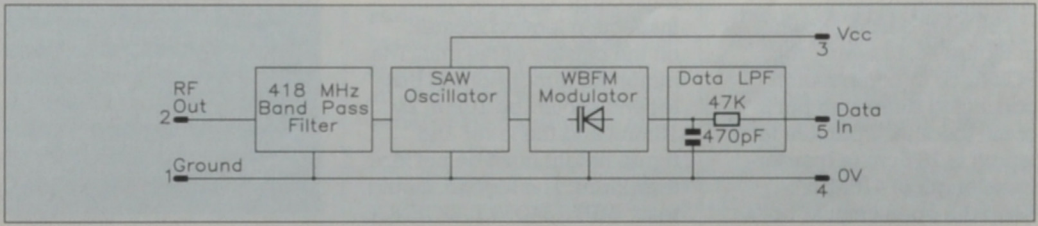


Figure 3. 418MHz transmitter module block diagram.

The filtered data is then passed to a wideband frequency modulator (WBFM) stage which will accept analogue AFSK or digital data from DC, to the 10kHz upper limit. Although the modulation bandwidth of the transmitter extends down to DC (as does the audio output of the receiver module), it is not possible to pass data with a DC component due to frequency errors and drifts between the transmitter and receiver. The WBFM modulator drives a varicap diode, the changing capacitance of which is used to modify the frequency of the next stage, a radio frequency (RF) oscillator. The centre working frequency of the RF oscillator is accurately set by a surface acoustic wave (SAW) resonator to be within the 418MHz band (417·90 to 418·1MHz). In addition to this, the RF oscillator has a 418MHz band pass filter (BPF) to ensure that any spurious out-of-band emissions are within the limits set by the RA's

Pin 1. RF GND – internally connected to pin 4.
Pin 2. RF out – connects to the integral antenna (50 Ω).
Pin 3. Positive power supply input.
Pin 4. 0V (ground) connection, for power and modulation.
Pin 5. Data input – CMOS logic driven.

Table 3. 418MHz transmitter module pinout.

MPT1340 specification. The final filtered RF output appears on pin 2 of the module.

MPT 1340 requires that the transmitter **must** only be used with an *integral* antenna. In this specification, an integral antenna is defined as one which is designed to be connected permanently to the transmitter without the use of an external feeder. Three types of integral antenna are approved for use with the TXM-418-A transmitter module – refer to Figures 4a, 4b and 4c.

Figure 4a shows the helical aerial, which is basically a wire coil connected directly to pin 2 at one end, and left free at the other. This antenna is very efficient given its small size (20mm length, 4mm diameter). The helical antenna has a high 'Q' factor, and thus needs to be optimised for the exact wavelength in use; trim the wire length or expand the coil for optimum results.

The loop aerial is shown in Figure 4b. As its name suggests, it consists of a loop of PCB track, which is tuned by a fixed or variable capacitor, and fed from pin 2 at a point 20% from the ground end, which is connected to pin 1.

The whip aerial, shown in Figure 4c, is a wire, rod, PCB track or combination connected directly to pin 2 of the module. Optimum total length is 16·5cm (a quarter-wavelength of 418MHz). Keep the open circuit ('hot') end well away from metal components to prevent serious detuning.

The choice of antenna and its position greatly influences the effective range of the transmitter. Table 4 compares the advantages of each of the three types. The best performance, by far, is where the aerial sticks out of the top of the finished boxed unit. This is often not desirable for practical or ergonomic reasons, and so a compromise may need to be reached. If an internal antenna *must* be used, try to keep it away from other metal components, batteries, PCB tracks/earth plane.

The equipment in which the transmitter module is fitted must carry a clearly visible inspection legend located on the outside of the unit. The minimum dimensions of this legend should be 10mm by 15mm, and the letter and figure height must be not less than 2mm. The legend should read 'MPT 1340 W.T. LICENCE EXEMPT'.

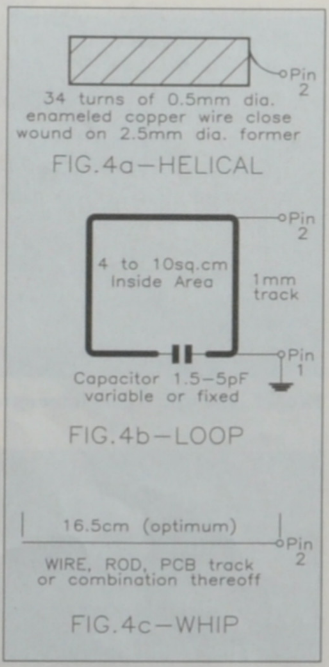

Pin 2
34 turns of 0.5mm dia. enameled copper wire close wound on 2.5mm dia. former
FIG.4a—HELICAL
Pin 2
4 to 10sq.cm Inside Area
1mm track
Pin 1
Capacitor 1.5–5pF variable or fixed
FIG.4b—LOOP
16.5cm (optimum)
Pin 2
WIRE, ROD, PCB track or combination thereoff
FIG.4c—WHIP

Figure 4. 418MHz transmitter antenna options: (a), helical; (b), loop; (c), whip.

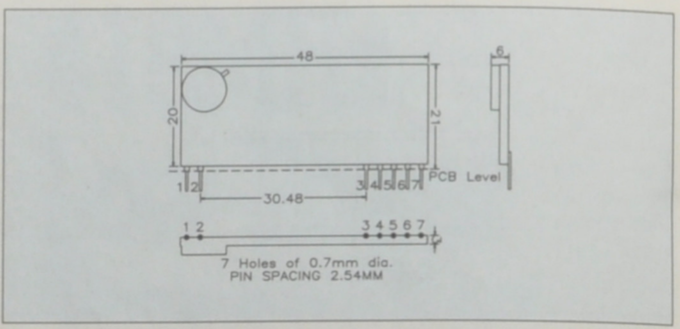


Figure 6. Physical dimensions of the Radiometrix SILRX-418-A 418MHz receiver module.

The trimmer control on the transmitter module is factory set and must never be adjusted. This control should not be made accessible in the final boxed unit.

Digital Code Transmitter

A circuit for a digital code transmitter (based around the UM3750 device) is shown in Figure 5. The transmitter module, TX1, can be mounted vertically to your main circuit board; or it could be carefully bent over to a horizontal position. When designing your PCB, you should observe RF layout practices.

The circuit design uses the UM3750 single chip encoder/decoder and is put into its encode (transmit) mode by connecting pin 15

Antenna selection	Helical	Loop	Whip
Ultimate performance:	Good	Fair	Excellent
Ease of design setup:	Good	Fair	Excellent
Size:	Excellent	Good	Fair
Immunity to proximity detuning:	Good	Excellent	Fair

Table 4. Transmitter aerial selection criteria.

Pin 1. RF input – connection for antenna (50Ω).
Pin 2. RF ground – internally connected to pin 4.
Pin 3. Carrier detect – used to enable external circuits.
Pin 4. 0V (ground) connection, for power and outputs.
Pin 5. Positive supply input.
Pin 6. Audio out – FM demodulated output.
Pin 7. Data out – digital output.

Table 5. 418MHz receiver module pinout.

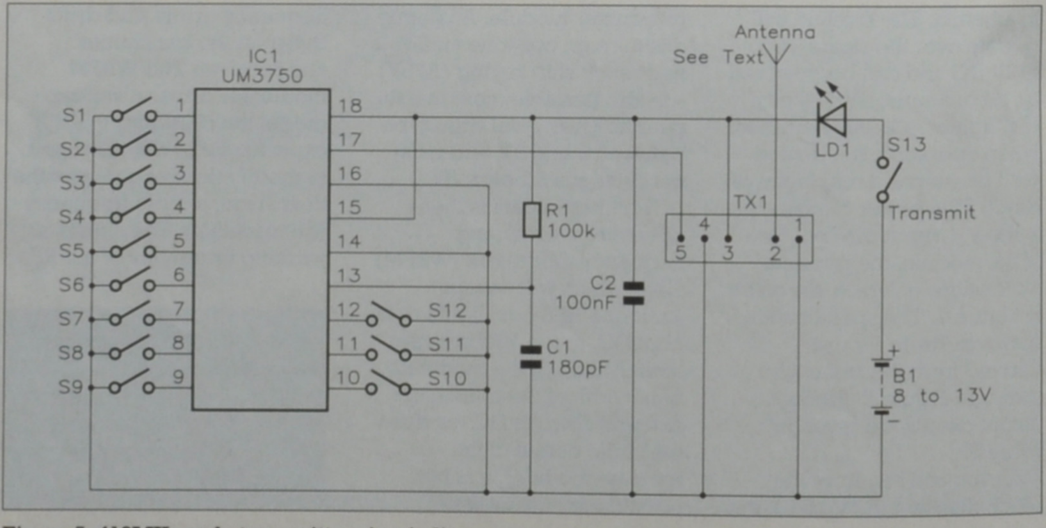
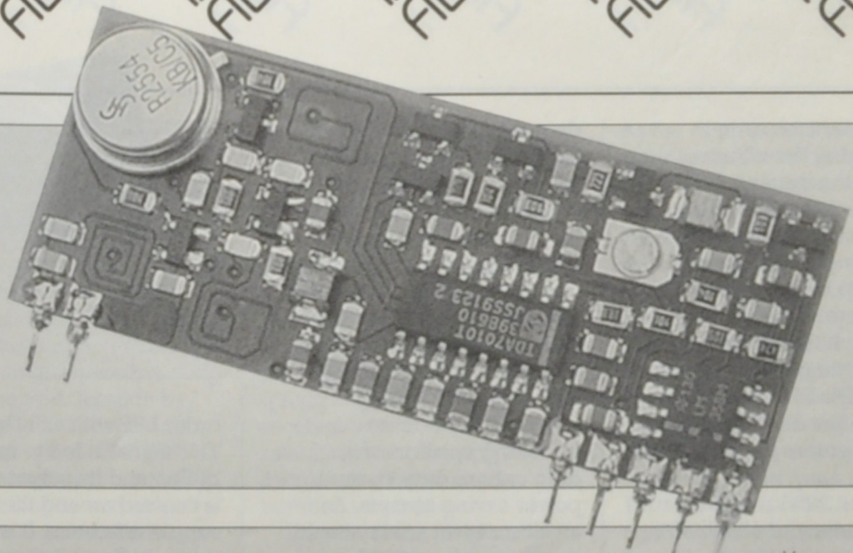


Figure 5. 418MHz code transmitter circuit diagram.

to V_{CC}. The code pattern is set by switches S1 to S12 on pins 1 to 12 of IC1 and a total of 4096 different codes are possible, with the timing of the system set by R1 & C1. The resulting digital code, appearing on pin 17, is fed to the modulation input, pin 5, of the transmitter module. The power for the circuit is normally supplied by a small battery, giving between +8 and +13V DC. When operating, the transmitter circuit is activated each time the transmit switch S13 is closed, causing current to flow, and LD1 to illuminate.



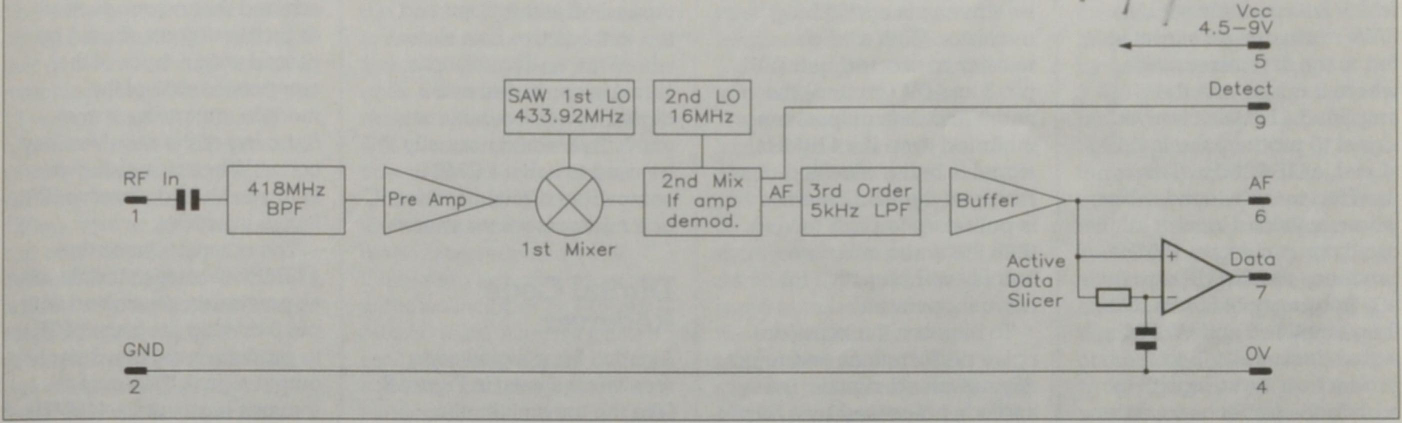


Figure 7. 418MHz receiver module block diagram.

The SILRX-418-A Receiver Module

The receiver module is a double-conversion FM superhet with a data level converter driven by the audio output buffer. All the stages of the receiver are powered from a single +4·5 to +9V DC supply (maximum current 15mA), which is applied to pin 5 of the module. For the module's physical dimensions see Figure 6; Table 5 shows the pinout.

Any of the aerials previously described in the transmitter section of this article may be used with the receiver module. However, the criteria for a receiver aerial under MPT 1340 are not as restrictive as those that apply to the transmitter. As an alternative to the integral aerial of the transmitter, you are permitted to use an external arrangement, connected by a coax feeder. If the range of the system is to be optimised, a quarter-wave dipole or ground plane antenna may be considered. As with the transmitter, the positioning of the receiver antenna is of the utmost importance and will prove

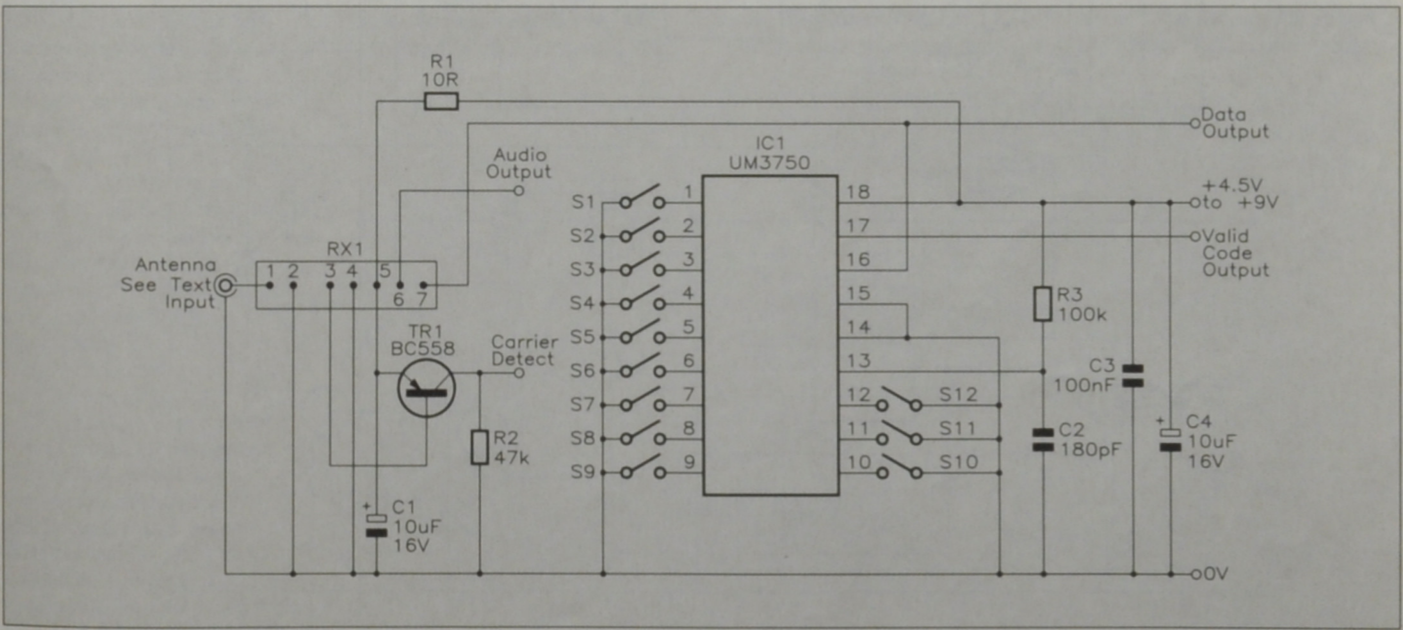


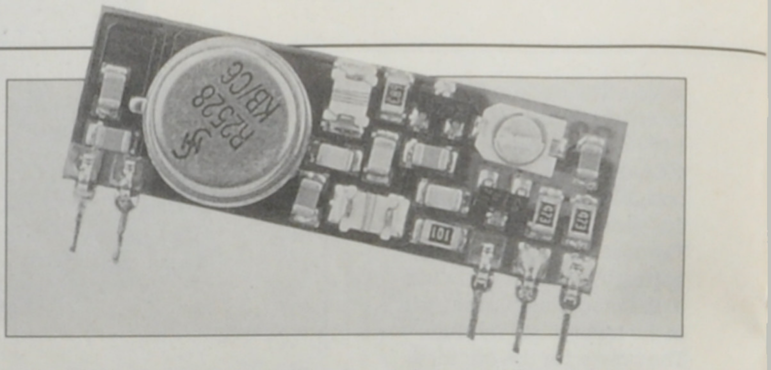
Figure 8. 418MHz code receiver circuit diagram.

an important factor in determining the ultimate range of the system.

Figure 7 shows the receiver in block diagram form. The incoming 418MHz signal, picked up by the antenna, is connected to pin 1 of the module where it then passes, via a coupling capacitor, into the 418MHz BPF. An RF preamplifier boosts the signal before it enters the first mixer stage.

The first local oscillator runs at a frequency of 433·92MHz, which is accurately set by a SAW resonator. Its output is fed to the first mixer stage, where it mixes with the amplified 418MHz received signal to produce the first IF signal, at 15·92MHz. This is then fed to the second mixer, where a second local oscillator running at 16MHz produces the final IF signal at a frequency of 80kHz. It is then amplified and WBFM signal demodulated to produce an audio signal. In addition, a fast-acting carrier detect signal is produced, which is made available on pin 3 of the module and may be used in several ways. This output could be used to create a general-purpose logic compatible output, via an open-collector transistor. This has much potential – indicating to external logic that a signal is being received, for remote switching applications, or to control duty-cycle power saving circuits. As an alternative, a relay could be driven via a switching transistor. With a 47kΩ resistor connected between pin 3 and 0V (ground) the audio and data outputs are inhibited even if a 418MHz signal is being received. Finally, if the 47kΩ resistor is pulled up to pin 5 (+V_{CC}), then the audio and data outputs will be active for normal operation.

To improve the signal-to-noise performance and reject any unwanted signals, the audio is processed by a third-order LPF with a 5kHz cut off. This signal is fed to an audio buffer, and its output (pin 6) is centred around the half-supply reference. It is also tapped off at this point and fed to the active data slicer, where the analogue audio signal is converted into a digital signal, available at pin 7. This would normally be used to drive a CMOS compatible digital decoder IC or a microprocessor system.



Digital Code Receiver

A circuit for a digital code receiver is shown in Figure 8. Like the transmitter, the receiver module can be mounted vertically or, by carefully bending the mounting/connection pins by 90°, horizontally. It is strongly advised that no conductive or ferrite objects should be placed within 4mm of the component side of the module, otherwise some detuning of the receiver may occur. When designing your PCB you should observe RF layout practices.

The connections to the 418MHz receiver module are as previously described with pin 3 driving the base of TR1 to produce a carrier detect output signal. This output remains high until a 418MHz

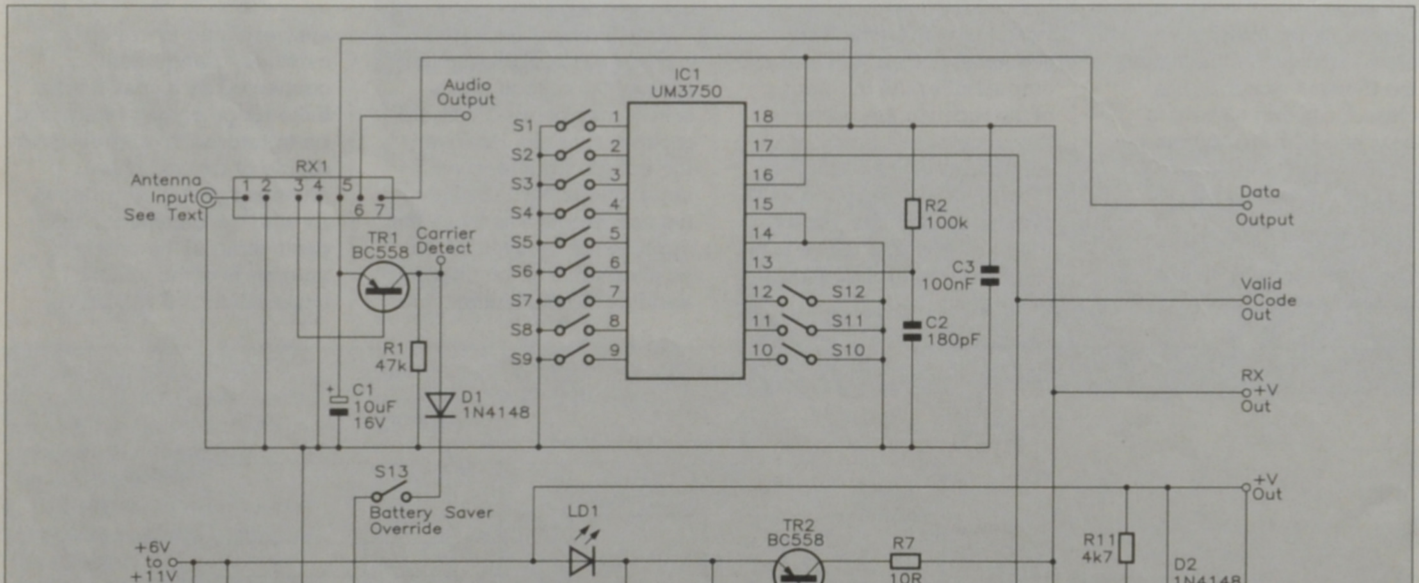


Figure 9. Circuit diagram of an expanded 418MHz code receiver, with 'battery saver' feature.

signal is received, at which time it goes low until the signal is removed. The audio output from pin 6 of the receiver module is not used in this application; however, the digital data output from pin 7 is used to drive another UM3750 (IC1) – this time, in its decode (receive) mode. This is achieved by connecting pin 15 of the IC to ground, and feeding the received data to pin 16. The values of R1 and C1 correspond to those used in the transmitter data system. The code pattern (one out of 4096) is set, using S1 to S12, to that of the transmitter, and if a matching code is received pin 17 will go low for 128ms. If a further match is detected within that time, the output will stay low for a further 128ms, and so on. This output can only sink 2mA for logic use and will require an additional transistor switching stage if higher current devices are to be controlled.

A more complex digital code receiver is shown in Figure 9. The additions to the basic receiver are a 'battery saver' circuit and an open-collector transistor switch. The battery saver function is based around a low-power 555 CMOS timer, IC2, which provides a duty cycle control function that latches on when a signal is present. The component values of R4, R5 & C7 have been selected to produce a 4ms 'on' time, and a 400ms 'off' duration i.e. a 1:100 duty cycle. This has the effect of significantly reducing the quiescent current consumption of the receiver, so increasing the battery life of the unit. Only when a 418MHz signal is received will the power to the receiver module, RX1, and the data decoder, IC1, be continuously applied. As soon as the received signal disappears, the 1:100 power supply duty cycle comes into effect once more.

The power saver function is achieved by connecting the carrier detect signal from buffer transistor TR1, via diode D1 and switch S13 (defeat), to pin 4 of IC2. While pin 4 is high (no signal received), the 555 timer will supply its pulse output to the receiver circuit. If a signal is received (or S13 is opened), however, then IC2 will produce a continuous output condition. This output is used to control the PNP power switching transistor, TR2. LD1, used to indicate when the receiver is active, will flash with a short duration pulse whenever signals are not being received. As soon as a valid signal is received (or S13 is open), then LD1 will stay permanently illuminated.

The valid code output on pin 17 of IC1 is fed, via R8, to the base of TR3, which is used to control the on/off switch action of TR4. When pin 17 goes low (transmitter and receiver codes match), TR4 will turn on, and current will flow in its collector circuit. This will cause LD2 to illuminate for the duration of the received valid code. If there are any other devices in the collector of TR4 (piezo buzzer, relay, filament bulb, etc.), you must ensure that the collector load does not exceed 75mA.

As with the transmitter, the trimmer control on the receiver module is factory set and must never be adjusted. This control should not be made accessible in the final boxed unit.

Other Transmission Formats

Digital code transmit/receive systems apart, it is possible to communicate using an audio tone format with, multiple, dual, or just a single tone of any frequency as long as it falls within the pass-band of the receiver – i.e. 10Hz to 5kHz.

Dual-tone multiple-frequency (DTMF) encoded signals are used to control a growing number of products and services. With an encoder chip, it would be possible to construct a pocket-sized keypad tone transmitter. The 418MHz receiver would require a matching decoder chip to recover the transmitted number sequence.

The transmission of radio teletype (RTTY) using audio frequency shift keying (AFSK) requires the accurate generation of two tones. These tones represent the logic conditions high or low, commonly referred to as mark and space tones respectively. To recover this data, the receiver requires an RTTY FSK demodulator system set to the same tone format as used by the transmitter. For more information on the RTTY system, please refer to *Best of Maplin Projects Book 3* (Order Code XC03D), for information on the TU1000 RTTY unit; *Electronics* Issue 39 (Order Code XA39N), for details of AFSK generator; and *Electronics* Issue 32 (Order Code XA32K), which describes a RTTY FSK demodulator.

Single Tone Signalling

A single tone, set to a precise audio frequency, can be used in much the same way as the digital code system previously described. When the frequency of the transmitted signal is matched by the tone decoder in the receiver, a valid output signal is generated. A circuit for a single audio tone transmitter is shown in Figure 10. An audio tone of 3·495kHz is accurately generated by using a 3·579545MHz quartz crystal, XT1, connected to the oscillator stage (pins 10 and 11) of IC1, a 4060BE 14-stage ripple counter. This has the effect of dividing the frequency of the crystal by 1,024, resulting in the 3·495kHz audio signal on pin 15, which drives the modulation input (pin 5) of the transmitter module TX1. It is possible to produce an almost infinite number of different audio tones by using an alternative crystal frequency and/or division output of IC1. Remember that the frequency of the audio tone must be within the pass-band of the receiver (i.e. 10Hz to 5kHz).

The power for the transmitter is normally supplied by a small battery, giving between +8V and +13V DC and the circuit is activated each time the transmit switch S1 is closed, causing current to flow, and LD1 to illuminate.

Single Audio Tone Receiver

A circuit for a matching single audio tone receiver is shown in Figure 11. The connections

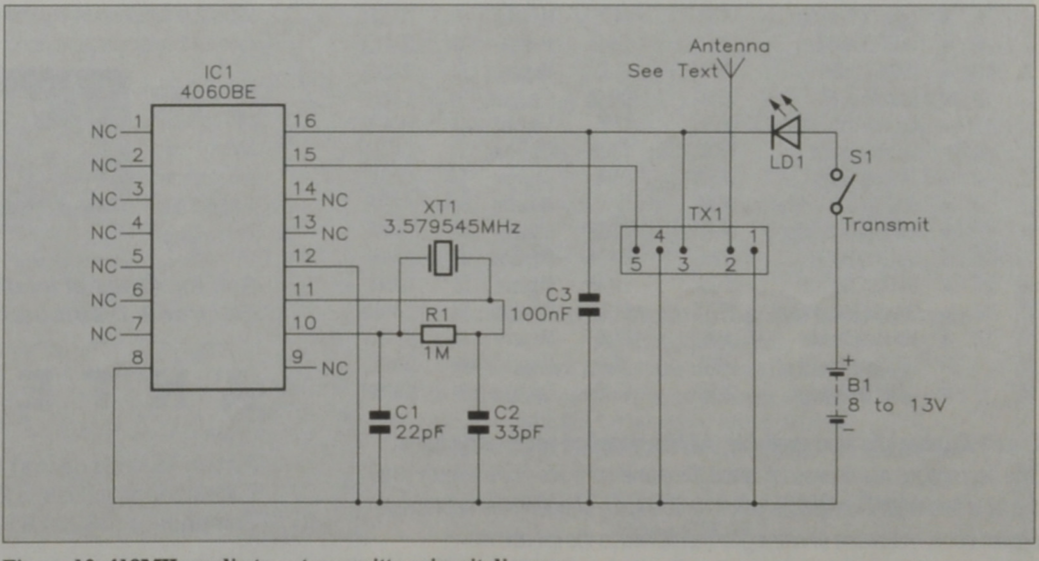


Figure 10. 418MHz audio tone transmitter circuit diagram.

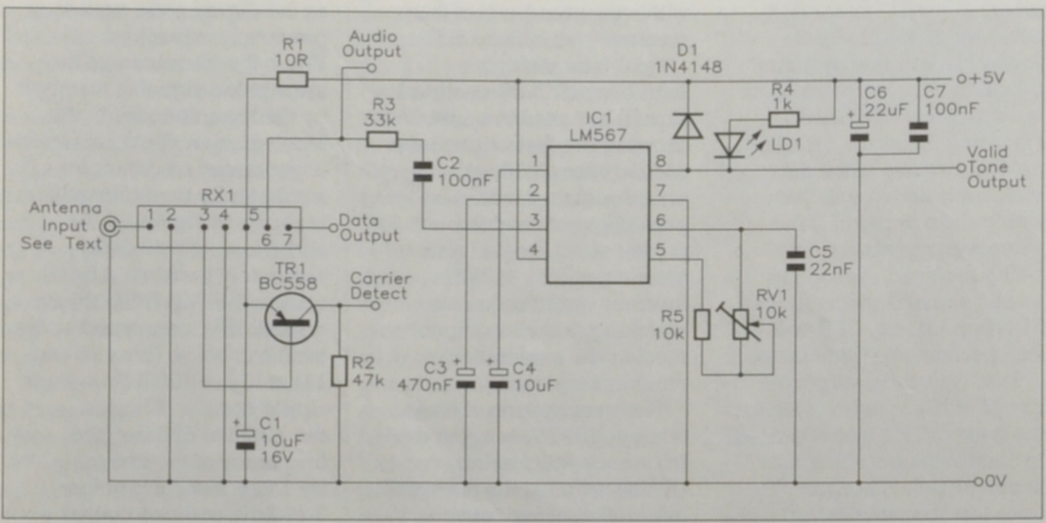


Figure 11. 418MHz audio tone receiver circuit diagram.

to the 418MHz receiver module, RX1, are as previously described, with pin 3 driving the base of TR1 to produce a carrier detect output signal. RX1, and the additional circuitry, are powered from a single +5V supply. The digital data output from pin 7 of the receiver module is left alone; however, the audio output from pin 6 is used to drive, via R3 & C2, the signal input on pin 3 of IC1 – a LM567 tone decoder. The frequency of IC1's current-controlled oscillator is set by the combined values of the fixed resistor R5, and the preset resistor RV1 on pin 5. The other end of this resistor chain is connected to pin 6 where it, and the value of capacitor C5, sets the phase locked loop (PLL) to the incoming frequency of 3·495kHz. Note that if a different audio tone is used by the transmitter, it may be necessary to alter the values of R5 & C5, to keep the tone within the range of RV1.

When the PLL frequency matches that of the transmitted tone, a positive match is made, and pin 8 of IC1 will go low for as long as this signal is received. This valid tone output condition is indicated by LD1. Additional devices can be driven (piezo buzzer, filament bulb, etc.) but *ensure* that the load does not exceed 75mA.

Recommended RF Design Practices

There should be less than 10mm of PCB track between the module and the antenna.

There should be an earth plane around all of the unused PCB areas that are close to the module.

The module should be mounted as far away as possible from any high-frequency interference sources.

MAPLIN'S TOP TWENTY KITS

POSITION			DESCRIPTION OF KIT	ORDER AS	PRICE	DETAILS IN		
1.	(2)	◆	Live Wire Detector	LK63T	£4.75	Magazine	48	(XA48C)
2.	(1)	◆	L200 Data File	LP69A	£4.75	Magazine	46	(XA46A)
3.	(3)	◆◆	TDA7052 1W Amplifier	LP16S	£4.95	Magazine	37	(XA37S)
4.	(4)	◆◆	1/300 Timer	LP30H	£4.95	Magazine	38	(XA38R)
5.	(7)	◆	Car Battery Monitor	LK42V	£9.25	Magazine	37	(XA37S)
6.	(8)	◆	Lights On Reminder	LP77J	£4.75	Magazine	50	(XA50E)
7.	(5)	◆	MOSFET Amplifier	LP56L	£20.95	Magazine	41	(XA41U)
8.	(10)	◆	LM386 Amplifier	LM76H	£4.60	Magazine	29	(XA29G)
9.	(9)	◆◆	Stroboscope Kit	VE52G	£14.95	Catalogue	'94	(CA11M)
10.	(13)	◆	Courtesy Light Extender	LP66W	£2.95	Magazine	44	(XA44X)
11.	(6)	◆	Electronic Ignition	VE00A	£12.95	Catalogue	'94	(CA11M)
12.	(14)	◆	1A Power Supply	VE58N	£8.95	Catalogue	'94	(CA11M)
13.	(12)	◆	SL6270 AGC Mic Amplifier	LP98G	£8.75	Magazine	51	(XA51F)
14.	(18)	◆	IBM Expansion System	LP12N	£21.95	Magazine	43	(XA43W)
15.	(16)	◆	8-bit I/O + RS232	LP85G	£19.95	Magazine	49	(XA49D)
16.	(20)	◆	UA3730 Code Lock	LP92A	£11.45	Magazine	56	(XA56L)
17.	(19)	◆	Universal Mono Preamp	VE21X	£5.95	Catalogue	'94	(CA11M)
18.	(17)	◆	Mini Metal Detector	LM35Q	£7.25	Magazine	48	(XA48C)
19.	(–)	RE-ENTRY	LED Xmas Tree	LP83E	£9.95	Magazine	48	(XA48C)
20.	(15)	◆	LM383 8W Amplifier	LW36P	£7.95	Catalogue	'94	(CA11M)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

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418MHz APPLICATION CIRCUITS PARTS LISTS

CODE TRANSMITTER

RESISTORS: All 0·6W 1% Metal Film

R1	100k	1	(M100K)

CAPACITORS

C1	180pF Ceramic	1	(WX59P)
C2	100nF 16V Miniature Disc Ceramic	1	(YR75S)

SEMICONDUCTORS

LD1	3mm Red LED	1	(WL32K)
IC1	UM3750	1	(UK77J)

MISCELLANEOUS

TX1	418MHz Transmitter Module	1	(AM27E)
S1 to S8	8-way DIL Switch	1	(QY70M)
S9 to S12	4-way DIL Switch	1	(JH08J)
S13	Miniature Push to Make Switch	1	(JR89W)
	18-pin DIL IC Socket	1	(HQ76H)
B1	9V Alkaline PP3 Battery	1	(FK67X)
	PP3 Battery Clip	1	(HF28F)

CODE RECEIVER

RESISTORS: All 0·6W 1% Metal Film

R1	10Ω	1	(M10R)
R2	47k	1	(M47K)
R3	100k	1	(M100K)

CAPACITORS

C1,4	10µF 16V Radial Electrolytic	2	(YY34M)
C2	180pF Ceramic	1	(WX59P)
C3	100nF 16V Miniature Disc Ceramic	1	(YR75S)

SEMICONDUCTORS

IC1	UM3750	1	(UK77J)
TR1	BC558	1	(QQ17T)

MISCELLANEOUS

RX1	418MHz Receiver Module	1	(AM28F)
S1 to S8	8-way DIL Switch	1	(QY70M)
S9 to S12	4-way DIL Switch	1	(JH08J)
	18-pin DIL IC Socket	1	(HQ76H)

CODE RECEIVER (WITH BATTERY SAVER)

RESISTORS: All 0·6W 1% Metal Film

R1,3	47k	2	(M47K)
R2	100k	1	(M100K)
R4,11	4k7	2	(M4K7)
R5	470k	1	(M470K)
R6,8,9	10k	3	(M10K)
R7	10Ω	1	(M10R)
R10	22k	1	(M22K)

CAPACITORS

C1,4,8	10µF 16V Radial Electrolytic	3	(YY34M)
C2	180pF Ceramic	1	(WX59P)
C3,5	100nF 16V Miniature Disc Ceramic	2	(YR75S)
C6	10nF 50V Disc Ceramic	1	(BX00A)
C7	1µF 63V Radial Electrolytic	1	(YY31J)

SEMICONDUCTORS

D1,2	1N4148	2	(QL80B)
LD1	5mm Red LED	1	(WL27E)
LD2	5mm 2mA Red LED	1	(UK48C)
TR1,2	BC558	2	(QQ17T)
TR3,4	BC548	2	(QB73Q)
IC1	UM3750	1	(UK77J)
IC2	TS555CN	1	(RA76H)

MISCELLANEOUS

RX1	418MHz Receiver Module	1	(AM28F)
S1 to S8	8-way DIL Switch	1	(QY70M)
S9 to S12	4-way DIL Switch	1	(JH08J)
S13	2-way DIL Switch	1	(JH09K)
	8-pin DIL IC Socket	1	(BL17T)
	18-pin DIL IC Socket	1	(HQ76H)
	Piezo Buzzer	1	(KU58N)

AUDIO TONE TRANSMITTER

RESISTORS: All 0·6W 1% Metal Film

R1	1M	1	(M1M)

CAPACITORS

C1	22pF Ceramic	1	(WX48C)
C2	33pF Ceramic	1	(WX50E)
C3	100nF 16V Disc Ceramic	1	(YR74S)

SEMICONDUCTORS

LD1	3mm Red LED	1	(WL32K)
IC1	HCF4060BEY	1	(QW40T)

MISCELLANEOUS

TX1	418MHz Transmitter Module	1	(AM27E)
XT1	3·579545MHz Crystal	1	(UJ03D)
S1	Miniature Push to Make Switch	1	(JR89W)
	16-pin DIL IC Socket	1	(BL19V)
B1	9V Alkaline PP3 Battery	1	(FK67X)
	PP3 Battery Clip	1	(HF28F)

AUDIO TONE RECEIVER

RESISTORS: All 0·6W 1% Metal Film (Unless Stated)

R1	10Ω	1	(M10R)
R2	47k	1	(M47K)
R3	33k	1	(M33K)
R4	1k	1	(M1K)
R5	10k	1	(M10K)
RV1	10k 22-Turn Cermet Preset	1	(UH25C)

CAPACITORS

C1,4	10µF 16V Radial Electrolytic	2	(YY34M)
C2,7	100nF 16V Miniature Disc Ceramic	2	(YR75S)
C3	470nF 63V Radial Electrolytic	1	(YY30H)
C5	22nF Polyester Layer	1	(WW33L)
C6	22µF 16V Radial Electrolytic	1	(YY36P)

SEMICONDUCTORS

D1	1N4148	1	(QL80B)
LD1	5mm 2mA Red LED	1	(UK48C)
TR1	BC558	1	(QQ17T)
IC1	LM567CN	1	(QH69A)

MISCELLANEOUS

RX1	418MHz Receiver Module	1	(AM28F)
	8-pin DIL IC Socket	1	(BL17T)

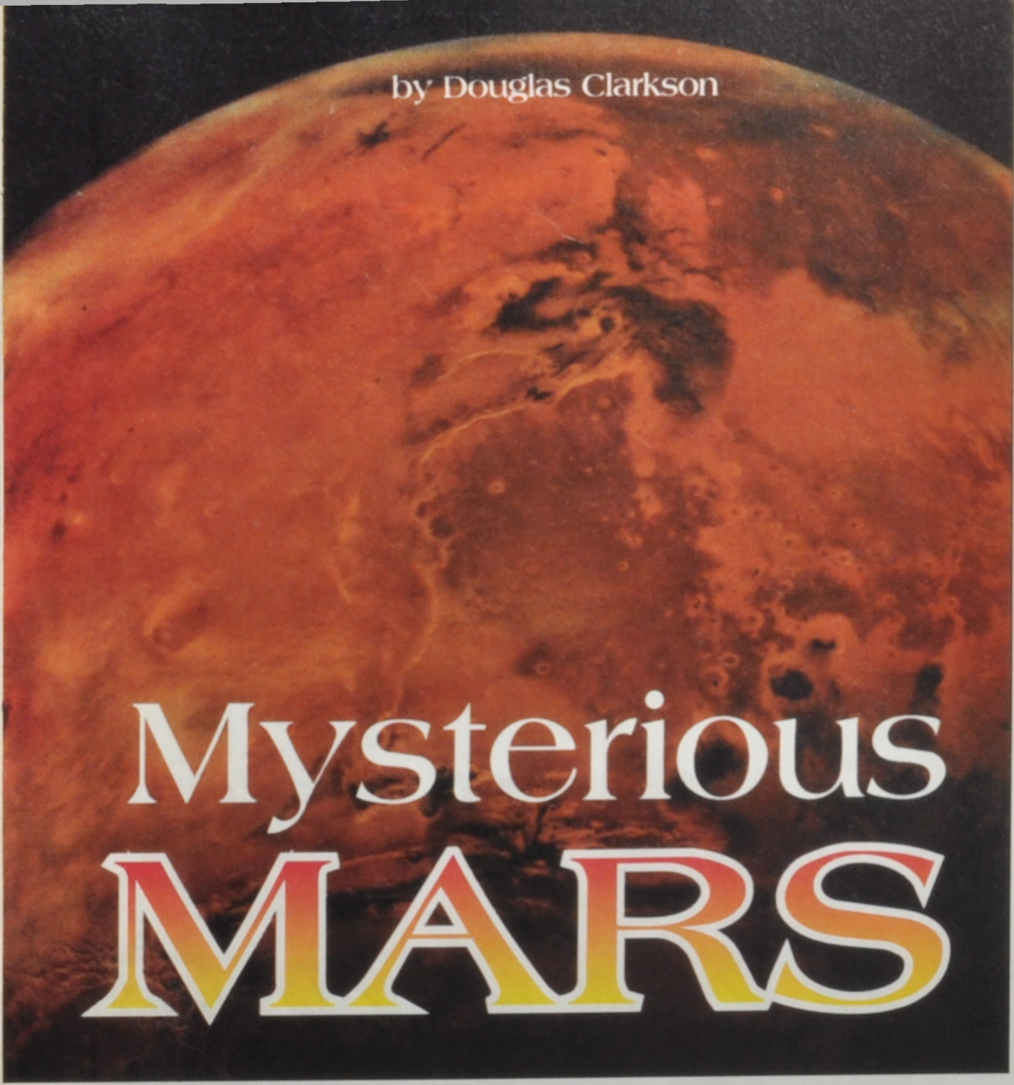
The Maplin 'Get-You-Working' Service is not available for these projects.

The above items are not available as kits.

The following new items, which are shown in the 1994 Maplin Catalogue, are available.

Order As AM27E (TMX-418-A 418MHz Transmitter) Price £17.95.

Order As AM28F (SILRX-418-A 418MHz Receiver) Price £29.95.



by Douglas Clarkson

Mysterious MARS

The Dreamer's Planet

This present stage in understanding the Earth's own processes for maintaining its fragile fold of life within the Ecosphere can be described as in its infancy. This is in spite of tens of thousands of man years of intense scientific research being undertaken to seek the relevant answers. Basic secrets of the oceans whichdetermine, for example, the carbon dioxide balance in the Earth's atmosphere are only now coming to light.

Investigating Mars, by present limited planetary exploration, with its own set of 'Martian house rules' and its own unique planetary history is in many ways like reading the outer cover of a book whose secrets can only be unravelled slowly. However, it has become clear that Mars may have just as many surprises locked in its wrinkled surface as the green and watery Earth. What might be there is for future generations of researchers to determine in detail. There is awareness that major events which took place on Mars may have coincided with similar changes on Earth – witness the many periods of fossil record 'extinction' now evident on Earth. However, it is good that the exploration of Mars has now begun.

Based on the information already obtained from Mars missions, it is possible to take a guided tour 'in imagination' over its rock strewn plains, the sites of ancient craters, empty channels where vast amounts of water once probably flowed, great canyons with vast landslides and the sites of vast volcanoes round which clouds of water vapour swirl.

In this much we can appreciate the planet's appearance and it is always a challenge to know this more intimately. However, visual appreciation of the surface landscape is only the first step in obtaining a detailed understanding of mysterious Mars.

Historical Observations

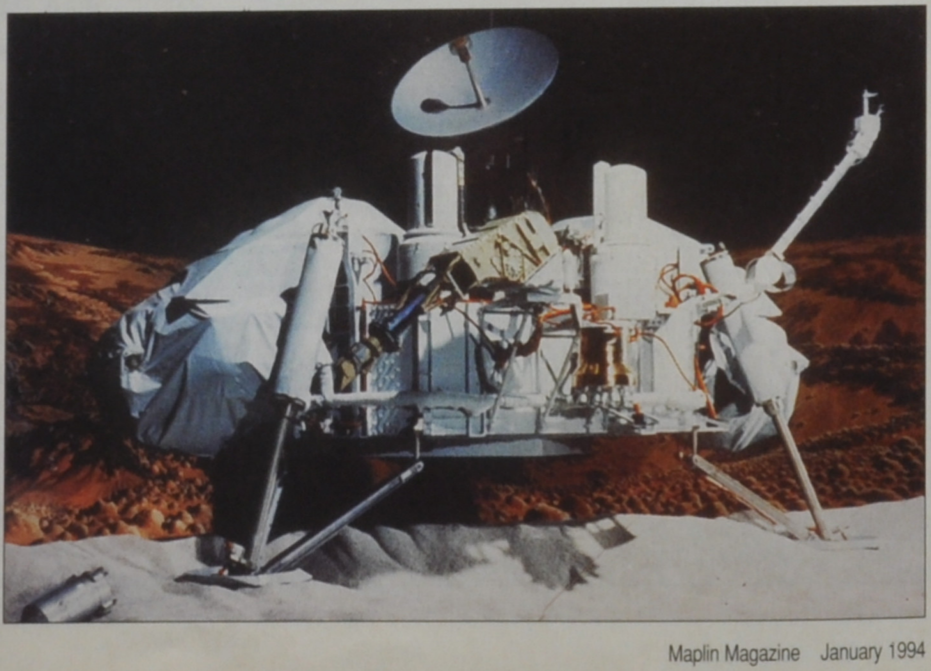
It was Galileo Galilei in 1610 who first observed Mars through the telescope, though it was Huygens in 1659 who was first able to detect dark markings on the planet's surface. The polar caps were first observed by Cassini around 1666 who was also the first to accurately measure the rotational period of the planet.

It was only in the 19th century that telescope observations of Mars began to indicate that the planet had features which were 'dynamic'. White areas at the north and south poles of the planet were seen to change with the planet's seasons. A 'wave of darkening' was observed to move away from the poles as the white areas receded around each polar cap. This wave of darkening was observed to spread out from each pole at a rate of 35km per day – spreading southwards from the melting northern pole and northwards from the melting southern pole. However, subsequent observations have shown that this phenomenon is probably an optical illusion triggered by atmospheric dust, and changes in air density. It does not appear to be a true surface phenomenon.

From time to time it is known that the entire surface of Mars becomes covered by dust storms. This may have been a factor in changing from time to time the appearance of the planet to Earth bound telescope gazers.

Various observers claimed to see what were described as canals on the Martian surface. The most famous 'canal watcher' was Giovanni Schiaparelli who produced a map in 1877 showing basic features which are represented in more modern maps of the planet. However, the canals have been shown to be an optical illusion. Anticipation of what these canals could have represented caught the public's imagination. Mars was portrayed as a world where vast canals fed water to areas of seasonal vegetation. In fact a NASA artist's impression of the planet Mars in 1971, prior to the Mariner 9 mission, still showed 'canals' linking up parts of the planet surface.

Below: Photo 1. An artist's impression of the Viking lander on the Martian surface.



Above left: Photo 2. Picture from the Viking I lander site showing rocks and sand dunes in remarkable clarity.
Above right: Photo 3. Photo showing the first colour photograph from the Viking I lander. The ground may be rising to the rim of an ancient crater.
Below left: Photo 4. View from Viking II over the Utopian Plane. The apparent slope of the horizon is due to the angle at which the craft settled on the surface.
Below right: Photo 5. Sampler scoop and arm of the Viking I lander. This was used to collect soil samples to look for signs of life on the Martian surface.

Planetary Exploration

It was planetary probes which were to revolutionise the understanding of Mars. This process began in earnest by the Mariner 4 fly past of July 1965. A series of more detailed pictures were obtained by Mariner 6 during 1969 – just after the triumph of the Apollo 11 landing. The Mariner 9 mission of 1971 placed a craft in orbit round Mars and paved the way for the highly successful Viking missions.

In particular, the Mariner 9 mission provided evidence of episodes of Martian history where large amounts of water were present on the Martian surface. River channels as much as 100 miles across were observed. Mars in the past has probably experienced vast climatic upheavals.

Several Martian missions were also initiated by the Soviet Union, though with less success than those of the USA. The Mars 2 probe, launched in May of 1971, placed a capsule into the planet's atmosphere though it is not clear if this landed safely on the planet's surface. The Mars 3 probe was the first craft to soft land on the planet's surface on 2nd December 1971. However, it landed in the middle of a dust storm and transmitted data for approximately 20 seconds. The Mars 5 mission of February 1974 returned a valuable set of scientific data – particularly of the planet's magnetic field.

Of the Phobos 1 and Phobos 2 missions of 1988, only that of Phobos 2 was partially successful. Phobos 1 was lost in August 1988 – a month after launch it was erroneously told by a radio command to close its systems down. Phobos 2 was within two hours of reaching Phobos in March of 1990 when contact was lost with the probe. In the changed reality of the disintegration of the Soviet Union, there is uncertainty about future missions to Mars. However, it is likely Russia, the core state of the CIS, will increasingly engage in co-operative ventures.

The process of exploration is still in progress. However, the Mars Observer project which should have reached Mars during August 1993 is unfortunately not sending back any data, and its fate is unknown. Perhaps towards the end of the century another lander with a rover vehicle to traverse the planet surface will be launched to further develop our understanding of the planet.

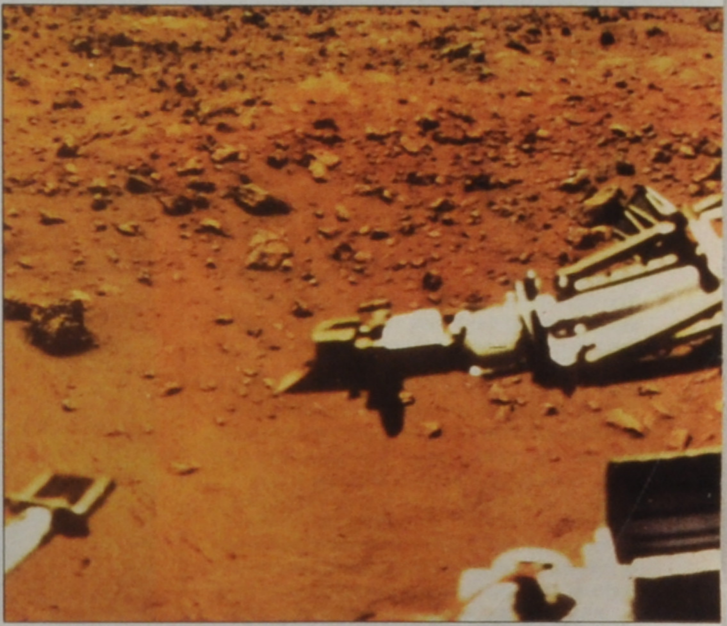
There have been many studies of proposed manned flights to Mars and most observers indicate that the principal problem is not technology – rather funding. 'Economical' manned trips to Mars cost upwards of $25 billion and it is becoming more difficult convincing the tax paying public that this is money well spent. It is well worth remembering that the Iran-Iraq war is considered to have cost $200 billion and current global arms sales cost in excess of $1,000 billion. Clearly a vast amount of money has been squandered and continues to be squandered.

Mars Some Facts and Figures

From Table 1 we can see that Mars is further away from the sun than the Earth and receives on average less than half of the solar radiation per unit of area than does the Earth.

The mass of Mars is considerably less than that of the Earth and the gravity at the planet surface is about one third that on the Earth. The duration of the Martian day, is remarkably similar to that of the Earth – a difference of only 37 minutes. However, the Martian 'year' is almost twice as long as that of the Earth's.

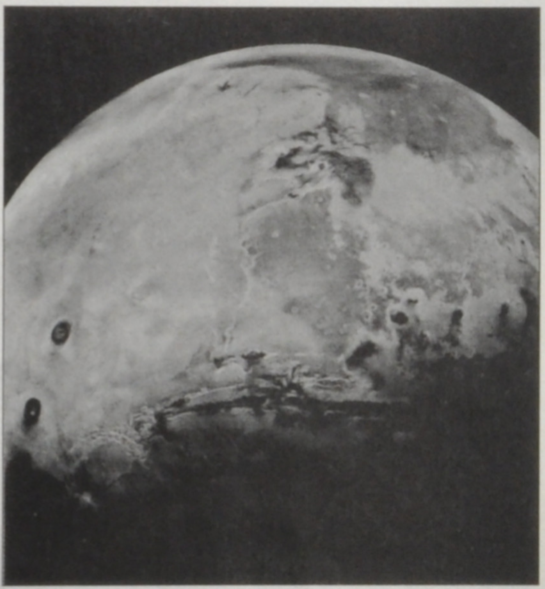
Planets in orbit round the sun travel in elliptical orbits rather than circular ones. The orbit of Mars is considerably more eccentric than that of the Earth and this introduces significant changes in the

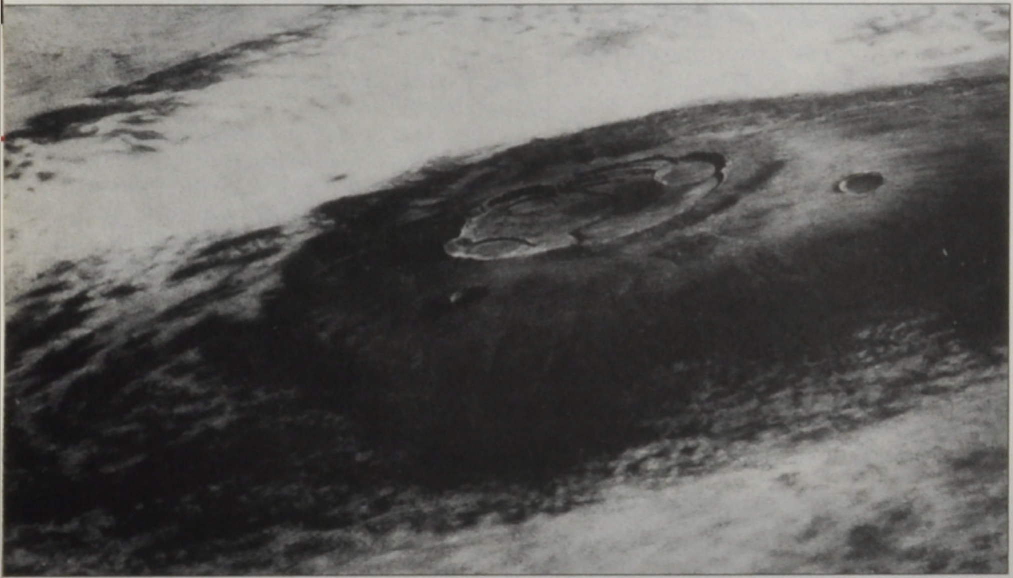


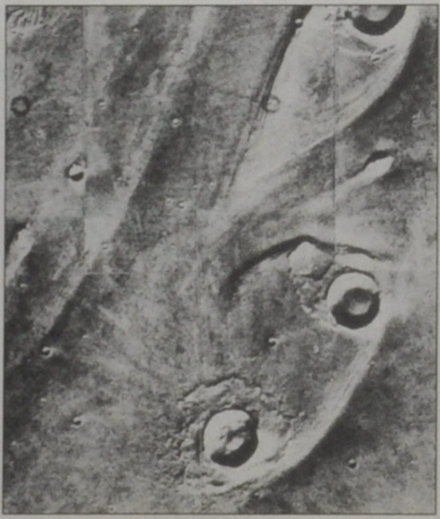
amount of solar radiation received at the planet's surface. At the closest approach, Mars is 206,600,000km from the sun, and at its furthest distance 249,200,000km from the sun. This gives rise to a variation of about ±20% in solar radiation from mean distance values of the sun's radiation. This effect is hardly noticeable on Earth since the Earth's orbit is much less eccentric. This introduces one significant variable to be taken account of in trying to appreciate Mars's complex climate pattern.

	Value for Mars	Fraction of Earth's Value
Mean Distance from sun	228,000,000km	1·53
Equatorial Radius	3397km	0·53
Eccentricity	0·093	5·5
Mass of planet	6·42 x 10^{26}kg	0·11
Mean surface gravity	3·72m/s^{-2}	0·38
Mean Martian solar day (sol)	24hr 37mins	1·03
Martian 'year'	697 days	1·91
Angle of axis to orbit plane	25°	1·06

Table 1: Basic facts about Mars.







Top left: Photo 6. Evidence of clouds forming in craters on Mars.
Top centre: Photo 7. Reconstructed photograph from 104 images taken by the Viking I orbiter spacecraft. Mars has a rich variety of surface features. The Valles Marineris a giant rift valley structure which extends for over 3,000 miles across the planet's surface is clearly visible.
Top right: Photo 8. Viking orbiter picture of features within the Valles Marineris showing evidence of possible water channels from earlier periods of the planet's history.
Above: Photo 9. Orbital view of Olympus Mons – Mars's highest volcano showing its crater and trains of cloud – assumed to be of water vapour which forms as air is cooled as it crosses over the volcano's features. A vast cliff is visible on the lower side of the picture.
Right: Photo 10. This picture provides evidence of periods of Mars history when large amounts of surface water flowed across the planet's surface. The figure shows what is thought to be an ancient river channel some 100 miles wide.

Another significant factor in understanding the Martian climate is introduced by the tilt of the axis of Mars to the plane of its orbit. This tends to make the seasons of unequal length.

The Viking Missions

The Viking I and Viking II missions to Mars must rank among the most successful of any mission to explore the planets of the Solar System. Prior to any data received from the current Mars Observer mission, it is the data from the Viking craft, and in particular the landers, on which present understanding of the planet is based. The Viking mission was also expensive – in the region of $1 billion in 1977 – about $2 billion at current prices.

Each Viking craft carried an orbiter vehicle and a lander module. Viking I was launched on 20th August 1975 and Viking II followed on 9th September. Some 10 months later on 19th June 1976 Viking I was placed in an orbit round Mars in anticipation of landing on Mars on 4th July – a climax to the bicentennial celebrations of the United States of America. (See Photo 1.)

Pictures taken by the Viking I orbiter craft, indicated rocky terrain on the initial landing area and a decision on the landing was delayed. An eventual safe landing was made on 20th July on Chryse Planitia.

The landing was essentially a three stage process. Initially rockets were fired for 22 minutes to lower the craft towards the surface. When the top of the Martian atmosphere was detected a large parachute was deployed and close to the surface a series of rocket motors slowed the landing speed to a brisk walking pace. The landing system had to work independently of mission control since command signals would have taken around 19 minutes to reach the craft. Both landers were lucky to make good landings although one of the landing legs of Viking II may have been damaged.

The television cameras on the Viking landers could swivel round to provide a 360° field of view, and pictures showed a landscape of boulders and small stones with material clearly deposited by surface wind. Such scenes were not unlike many desert landscapes on Earth. Computer enhancement of the Viking images gave them surprising sharpness and clarity of detail as shown in Photo 2.

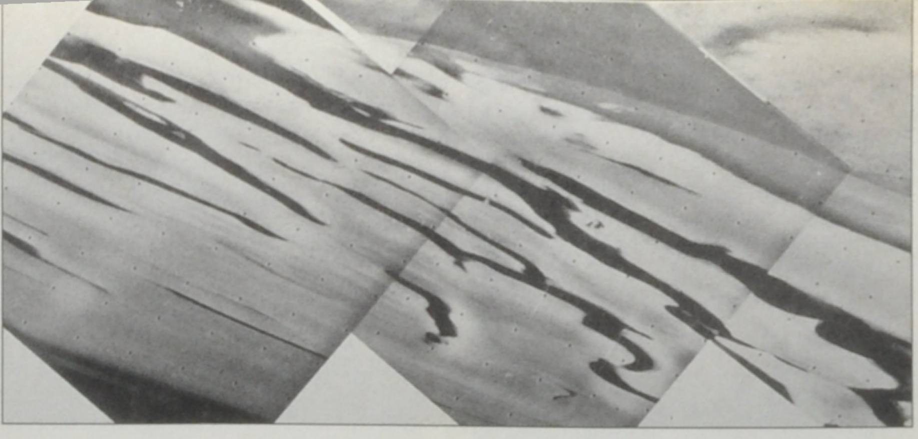
The first colour photograph of Viking I is shown in Photo 3. The ground may be rising to the rim of an ancient crater. The landscape is that of a surface strewn with rocks of various sizes overlain with reddish brown dust. The reddish colour is thought to be the result of chemical reaction between iron bearing compounds and water vapour – similar to 'rusting' on Earth. Considering the relatively rough terrain around the Viking I site, the craft was indeed lucky to have made so good a landing. The first colour photograph shown to the public was shown with a blue Earth-like sky. This was later corrected to show a pink sky.

Viking II was all the time approaching Mars and was placed in orbit round the planet on 7th August. Again it was found necessary to rescan the surface for a new landing site. The region of Utopia Planitia was chosen since this appeared to be a region with numerous sand dunes. These would be a contrast to the rocky terrain of Chryse Planitia. After another successful landing, the first images to appear were of a landscape similar to that of Viking I – rocks and more rocks. Photo 4 shows a view over the Utopian Plain. The apparent slope of the horizon is due to the angle at which the craft settled on the surface.

Both landers had been equipped with sophisticated systems to scoop up and analyse soil samples. Photo 5 shows the sampler scoop and arm of the Viking I lander. During the collection process, soil was removed from a trench some 3in. wide and 2in. deep and then the contents dropped into a hopper which fed material to various 'life search' experiments. The soil appeared to have the consistency of wet sand.

One experiment using a gas chromatograph/mass spectrograph scanned the samples for evidence of organic molecules. None were found. One theory was that any molecules which may have existed on the surface would be broken down by the high levels of ultra violet light bombarding the surface. While this experiment indicated that organic compounds do not exist on the very surface layers of the planet, such compounds could well exist at greater depths within the Martian soil.

In a separate series of experiments investigating biological activity, the results were inconclusive. Apparently positive results indicating the presence of Martian bacteria could also be attributed to exotic chemistry within the Martian soil.



Above: Photo 11. This picture, taken by Viking II, shows extensive dune fields which surround the northern polar region. These dunes are the most extensive dune areas so far discovered in the solar system.

Lander I carried on working until November 1982 (working for over six years) but Lander II stopped functioning on 11th April 1980 (working for less than 4 years). Prior to this, control had been lost of the orbiter craft. Orbiter I ran out of attitude control gas on 25th July 1978 while Orbiter II's gas ran out in the late summer of 1980. This meant that the Orbiter craft could not be controlled to direct its antenna down towards the Lander craft and so the mission effectively came to an end.

The Atmosphere of Mars

The mean surface pressure on Mars is approximately 1% of that of the Earth – about 7·5mbar. However, this mean level varies by as much as 26% due to the melting and reformation of frozen carbon dioxide on the Martian polar regions. It is estimated that as much as 8×10^{12} metric tons of CO_2 are cycled on an annual basis between the melting pole and a reforming pole.

It is thought that the residual pole caps are principally composed of water ice. The northern pole region in particular has a relatively large reserve of water ice.

The fact that vast reserves of water are locked up in the northern pole areas is a major positive finding of the Viking mission. Previously it was thought that the polar caps consisted entirely of frozen carbon dioxide – 'dry ice'. One of the more startling photographs taken by the Viking II orbiter indicates a vast ice cliff in the northern polar regions (see Photo 11). Presumably the lower gravity on Mars makes such vast ice cliffs more stable than they would be on Earth.

There is no doubt that future manned missions to Mars will set a high priority on drilling core samples from the polar regions in order to delve back into the chronicle of Martian climatic history. Similar studies in the Antarctic on Earth have allowed the composition of the Earth's atmosphere to be determined over periods of hundreds of thousands of years.

Gas	% Present
Carbon Dioxide	96·5
Nitrogen	1·8
Argon	1·5
Oxygen	0·1
Water vapour	0·02
(traces of Neon, Krypton and Xenon and Carbon Monoxide)	

Table 2: Composition (by weight) of the Martian atmosphere.

The composition of the Martian atmosphere is summarised in Table 2.

The discovery of nitrogen in the atmosphere (essential for life) was a major revelation of the Viking mission.

It is considered that significant amounts of the Martian atmosphere could have been lost into space as molecules high in the planet's atmosphere were split into their component atoms by high ultra violet radiation and imparted energies higher than the planet's escape velocity. Mars is probably too small to have kept hold of an atmosphere although during its earlier periods of development it could have sustained it. This is one of the vital questions which present and future Mars missions will seek to answer.

The Martian Climate

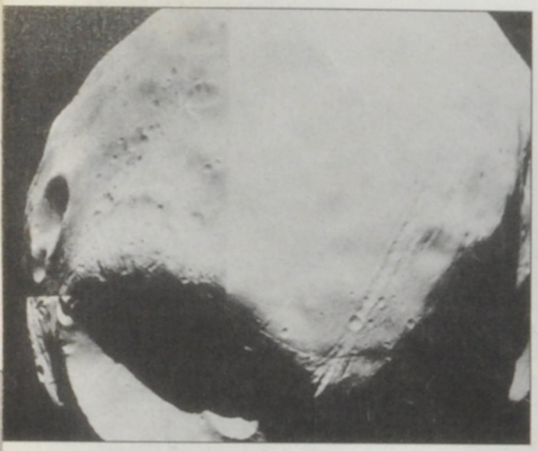
There is no doubt that if the Martian climate had been more welcoming it would have stirred up more interest in voyages of discovery to the Martian surface. At the Viking I lander site the typical lowest night time temperature was −86°C, and the highest day time temperature −33°C. On a warm day on Mars the surface temperature may rise to around 0°C near the equator.

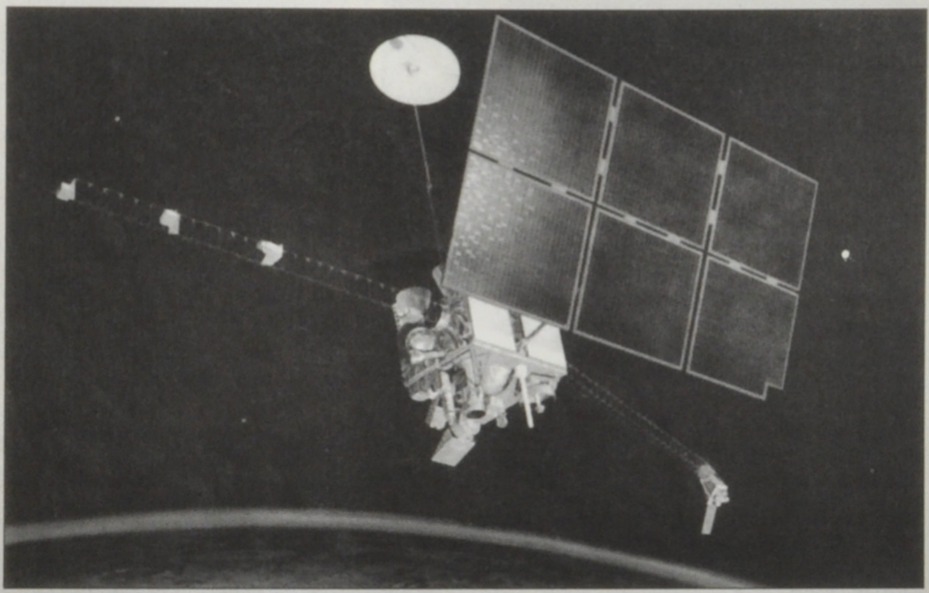
Surface temperatures have been found to be slightly higher than anticipated. This is due in the main to the presence of dust particles in the atmosphere which scatter and absorb solar radiation. This in fact gives the sky a pinkish colour.

The Martian weather is also more predictable than that on Earth where the influence of the oceans introduces more variability on weather processes. There are apparently no major career opportunities for weather forecasters on Mars! Presumably the Viking data set recorded temperature changes taking place during dust storms though such findings are not disclosed in mission summaries.

The variation in surface heating caused by differences in solar warming with terrain and latitude, establishes pressure gradients which give rise to winds in the atmosphere. Winds tend generally to be light and less than 10m/sec. Dust storms are a regular feature of the Martian climate. Local storms can become unstable and involve large parts of the planet's surface. This happened, for example, prior to the Mariner 9 orbiter mission.

Pictures of the landscape around the





Top left: Photo 12. This picture of Phobos, one of the moons of Mars was taken by Viking I at a distance of about 100 kilometres. It reveals a heavily cratered object which in the past suffered a major impact which has probably severely weakened its structure.
Above: Photo 13. Artist's impression of the in orbit details of the Mars Observer craft that should have achieved Mars Orbit during August 1993.

Viking lander sites show wind blown material which line up along the direction of the prevailing winds. However, once the wind speeds moderate, the atmosphere tends to clear rapidly. Dust deposited on the polar caps may act to accelerate melting as the dust more readily absorbs heat from solar radiation. One of the factors tending to encourage dust storms is the relatively low Martian gravity – about a third of that of Earth.

In the dry, arid conditions of Mars, the major factors determining topography changes will be wind erosion and landslips triggered possible by Mars quakes. Just as on Earth wind blown sand tends to be rounded by countless impacts against obstructions, so grains of sand and dust on Mars are likely to be rounded also. Both the landers were equipped with seismometers though only that of Viking I was deployed successfully.

Evidence of early morning fog was observed in craters as shown in Photo 6. This is considered to be caused by frost forming overnight on the floor of such craters which with the heat of the sun, evaporates to form a fog. Presumably enclosed craters are an ideal environment for levels of water vapour to build up and condense, and also for heating of the surface to be more effective within the crater walls.

Surface Features of Mars

Surface details of Mars exit on a surprisingly grand scale considering the size of the planet. Photo 7 shows a photograph derived from a mosaic of 104 images taken by the Viking Orbiter 1 spacecraft. The mosaic was created by the US Geological survey in Flagstaff, Arizona. The large elongated feature is Valles Marineris – a rift valley with steep sides which extends over 3,000 miles across the equatorial region of the planet. It is typically around 250 miles wide. In close up orbital scans, numerous landslips are visible along its path where material has cascaded into its deep chasm. Photo 8 shows the fine detail within the Valles Marineris – showing possible sites of erosion by water channels.

The set of three markings on the lower central left area of Photo 7 are volcanoes of the Tharsis Mountains – Arisa Mons, Pavonis Mons and Ascraeus Mons. Olympus Mons, considered to be the largest volcano in the solar system, towers some 17 miles above the mean level of the planet and is situated to the left of the 'line of three' volcanoes shown on the left of Photo 7. Olympus Mons is to date the largest volcanic structure known in the Solar System.

Photo 9, which is produced from photographs taken at lower altitude, shows clouds of water vapour clinging to the towering sides as the atmosphere cools in transit up its slopes. The base of the volcano is some 500 miles in diameter. There is no evidence of any present activity in the Martian volcanoes. However, it is likely that significant outgassing from these volcanoes could have significantly influenced the composition of the Martian atmosphere. The soil of Mars is apparently rich in sulphur compounds.

The Northern plains show little in the way of cratering. One possible explanation is that volcanic activity has in the distant past erased their features. However, around the northern pole vast dune fields have been discovered which are considerably greater in extent than any such features on the Earth.

While there is at present no evidence of surface water on present day Mars, there is significant evidence to indicate that in the past vast quantities of water did flow on its surface. This could have taken place at periods of rapid climatic change. Traces of rivers up to 100 miles wide have been detected as shown in Photo 10.

Photo 11 shows vast dune fields which entirely surround the northern pole of Mars. The deposits of these dune fields are considered to consist of materials once locked within a more extensive polar region. This area may be the prime source of dust which gives rise to planet wide dust storms.

The Moons of Mars

Phobos (fear) and Deimos (terror) were discovered by Asaph Hall in 1877, and as planetary investigations could only be detected as extremely small objects their dimensions could not be resolved.

However, Photo 12 shows a composite picture of Phobos formed from a mosaic of scans taken by Viking I when it was about 100km distant. Phobos is approximately 27 x 22 x 19km in size and its surface is heavily cratered with one crater the Stickney crater being around 10km in diameter. The striations clearly visible, resembling rock strata are extremely puzzling and may be associated with the initial impact – indicating that the satellite was almost split apart by the collision.

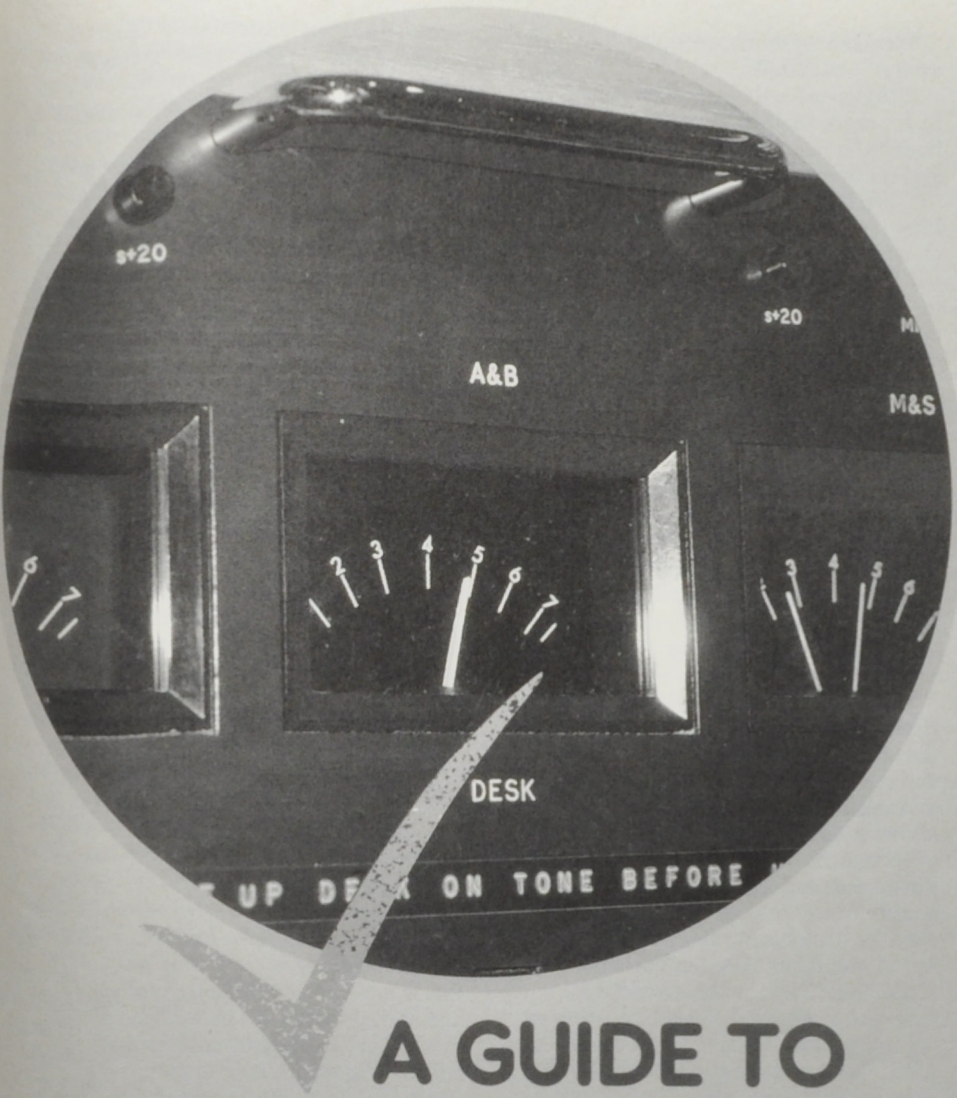
The Mars Observer Mission

Photo 13 shows an impression of the Mars Observer craft as it would have appeared in orbit round Mars. The main body is box shaped. The six-panel solar array of 7 x 3·7m was designed to generate 1·13kW of power for the craft's electronic circuits. A key element of the onboard instruments was a laser altimeter to 'range' the height of Mars under the craft and so build up a detailed topography map of the planet's surface. A full survey of the planet's surface would have taken one Martian year – 687 Earth days. Once the craft was initially placed in orbit a series of minor adjustments would have placed the craft into a near-circular 118 minute polar orbit some 378km above Mars.

On board instruments also included a thermal emission spectrometer, magnetometers, electron reflectometer, gamma ray spectrometer, pressure modulator and infra-red radiometer.

This mission had obvious similarities to the highly successful Magellan mission which mapped a very high proportion of the surface of Venus. The Mars Observer craft was based on the design of the RCA Satcom K communications satellite. Compared with the Viking mission, the $250 million price tag of the craft implies that this would have been a much cheaper mission.

Continued on page 56



A GUIDE TO PROFESSIONAL AUDIO

PART TEN

by T. A. Wilkinson

This month, to conclude the subject of audio 'recording' in this series, we take a whistle-stop tour of digital recording, its media and formats. But first, a few interesting thoughts.

PROBABLY, not since the introduction of stereo recording and reproduction has anything changed our perception, and the subjective quality, of recorded audio in the way that digital techniques have. And, although digital audio has been around for some time, it is really only in the last ten years that things have taken off in a big way. For it was ten years ago, in 1983, that Philips launched Compact Disc to an unsuspecting and rather reluctant consumer market.

Since that time there have been huge leaps forward in all areas of audio. You only need to compare the facilities offered by a modern inexpensive keyboard with that of a top flight model of ten years ago to appreciate how technically well off we are now.

Digital audio reaches out and touches us all every day, whether we like it or not! For example, most of the telephone network has been converted to digital operation; most pre-recorded music programmes on BBC network radio are digitally mastered onto DAT, much of the audio on TV is digitised and of course many people are now intimately acquainted with Compact Disc! The list is endless, but you get the picture.

Before we even begin to consider digital recording, we ought to ask ourselves "Well, why bother?" In fact there would be little point in developing digital recording systems if there were no benefits to be had in terms of the quality of the stored signal, and if digital techniques could not in some way better the analogue systems we all know and love!

The good news is, I think, that good and even fairly good digital recording systems can equal, and in many cases better, most analogue recording systems. Beyond these, some of the best digital systems simply leave analogue recorders on the starting grid!

The question is, can you tell the difference between good old analogue and the modern digital equivalent? The traditional Hi-Fi buffs would have us believe that the modern CD system is still inferior and produces 'less musical' results than the vinyl disc. But what exactly do they mean by 'less musical'? "Ah well, I mean it sounds clinical doesn't it?", or even "you can actually hear the holes in the digital recording!" These, and similarly degrading comments, all amount to the same thing, that is, digital recording sounds in some way different to analogue. The main cause of this is that a digitally encoded tape recording has none of the hiss or noise that is naturally inherent in all analogue tape systems; similarly, reproduction from a CD is not accompanied by the surface noise that comes free with every vinyl disc.

Before I dig a hole for myself here, the answer is yes, I have been down the road of minimalist, esoteric turntables and 'directional speaker cable' (but please don't tell anyone!), and I have come to the conclusion that using a compact disc based system with sensible (modest but capable) partnering equipment allows me to listen to the music rather than the Hi-Fi. Not only that, but now I can forget about RIAA correction, stylus tracking weights and the 'end-of-groove distortion' inherent on so many record playing systems. You would not believe how many times I tried, fruitlessly, to improve this latter problem. One vinyl disc in particular, Fleetwood Mac's Rumours, illustrates this point perfectly; the last track of side one (Songbird), a gentle vocal and piano arrangement, is ruined by end-of-groove distortion. But listen to it on CD and ah, almost perfect.

So yes, on the face of it, you can tell the difference, and on a pound for pound basis comparing, say, a £500 DAT recorder with a £500 analogue tape recorder, there is no doubt in my mind that the DAT machine would out-perform the analogue in terms of sheer quality. Musically? This I admit is somewhat subjective, and at the end of the day the system that's right for you is the one that gives you greatest listening pleasure regardless of the technology used to produce it. The reason? Well, we all have different ears, don't we! But I suspect that the professional user is looking for the ultimate in pure quality, with perhaps little regard for the cost. Or, to put it another way, the replayed recording must, as far as is possible, be an exact replica of the original sound – especially where mixing and re-recording is concerned.

This is not to say that digital

recording techniques are perfect, some are far from it, but the problem is not one of storing digital information on a medium, that's the easy bit. The serious problems lie with the A-to-D and D-to-A conversion and the way in which the audio is compressed and coded. In much the same way as with analogue recording methods, digital recording is a whole series of compromises.

In the most basic of terms, the incoming analogue audio signal (a continuous waveform) is sampled at high speed and thereby converted into a periodic signal, this is then 'quantised' and given numerical values. Added to these numerical values will be extra bits or numbers to be used as error correction and timing information. These extra bits are said to be 'redundant,' as they do not contribute directly to the audio signal, and cannot be used in the conversion of the digital signal into analogue format. The strings of digits are arranged into coded groups and are finally laid onto tape. Simple, eh? Well, as usual, it is not that simple and, like many of these things, one is amazed that it works at all!

For many – and I do not exclude myself – getting to grips with digital audio is made all the more difficult by the use of unfamiliar and high tech sounding words and phrases, techno-jargon and Three Letter Abbreviations (TLAs – sorry!). In an effort to clarify some of these there now follows a short glossary and very basic explanation of some of the most common digital audio terms.

Sampling Frequency

The Sampling Frequency (often simply referred to as 'FS') of any digital recording system will always be at least twice that of the highest frequency contained within the signal. For audio this means that the choice of FS must be greater than 2 x 20kHz, i.e., > 40kHz. There are two reasons for this.

If an audio signal is sampled at more than twice the highest frequency, it would appear that the sampled signal will have enough information contained within it to accurately recover the original signal, furthermore, any problems connected with 'aliasing' are also minimised.

In order to allow compatibility with competitors' equipment, and thus allow almost any tape to be used with any similar equipment, manufacturers have standardised on their choice of sampling frequencies. The three most common sampling frequencies used at the moment are:

44·1kHz – used in the PCM Sony F1/701/1610/1630 type systems, based around video recording media such as Betamax and U-Matic. CDs also use this FS, because mastering for CD was originally done using PCM systems, hence 44·1kHz is the chosen FS for all CD work. This seemingly odd choice of sampling frequency arose to give compatibility with both European 25Hz PAL and American 30Hz NTSC television systems, on which the PCM system was based.

PCM systems that use video recorders insert three digital samples per active line of the picture. On a 25Hz, 625 line system there are 588 active lines, whilst the 30Hz system uses 490 active lines. Now if we simply multiply the number of active lines by the number of samples per line by the frame rate, the answer for both the 25 and 30Hz systems is the same, i.e., 588 x 3 x 25 = 44,100Hz and 490 x 3 x 30 = 44,100Hz.

48kHz – this sampling frequency is considered as the 'no compromise' professional standard. Conversion to other sampling rates is fairly easy, and 48kHz works well with both film and TV production. DAT uses this FS as do many other professional digital tape recording formats. 48kHz is also the AES/EBU standard for the 'local' transfer of digital audio between studio and studio, mixer to mixer, etc., using for example fibre optics.

32kHz – this is the EBU (European Broadcasting Union) standard and is the earliest of the current standards, and was designed for use in audio signal distribution. Obviously 32kHz only allows a somewhat restricted bandwidth of around 15kHz, and whilst this is not considered as very suitable for high quality music recording, it is widely used for distributing signals in TV sound and AM/FM radio. The EBU has settled on 32kHz as the standard for long distance signal distribution. Some digital recorders also have an option for a 32kHz sampling rate, this can be used to increase the recording time capacity of the medium (at the expense of reduced bandwidth), a bit like the 'Long Play' option on video recorders.

Sample Rate Conversion

In certain situations it may be necessary to transfer data between equipment with dissimilar sampling frequencies, and therefore a conversion of the sampling rate is required. For example, conversion from 32kHz to 48kHz is a fairly straightforward 3:2 ratio, and can be achieved by three times oversampling 32kHz to 96kHz, followed by a division of two, resulting in 48kHz. Other conversions are not so easy; 44·1kHz to 48kHz is more common now, but at one time this required literally thousands of stages to complete, resulting in expensive conversion equipment.

Bits Per Sample

The number of Bits Per Sample (among other things) sets the dynamic range of the system, and the dynamic range is often quoted as (6 x n)dB, where 'n' is the number of bits per sample.

Thus, a 16-bit recorder would have a dynamic range capability of 6 x 16dB or 96dB; in this context a digital system can be considered as better than a similar analogue set up.

Signal to noise ratio is quantified in a similar way to dynamic range, again using the bits per sample factor. However, to make realistic comparisons with analogue equivalents, it is necessary to use the same measurement techniques with consideration for signal 'weighting' and peak operating levels.

In short, a more realistic and correct estimate of a digital recorder's signal to noise ratio would make use of a 'fiddle factor,' which effectively takes account of the above considerations. Thus the weighted signal to noise ratio is estimated as (6 x n –11)dB; where 'n' is the number of bits and '11' is the 'fiddle factor'. A 16-bit recorder would have an estimated signal to noise ratio of (6 x 16 –11)dB or 85dB, which still looks quite good when compared to a professional analogue recorder at around 60dB.

It is worth noting that for every extra bit added to a digital system, the number of quantising levels is doubled and the relative noise level will be halved. So, although the difference between 14- and 16-bit systems doesn't seem much (well it's only two bits, isn't it?) the actual potential difference in performance is quite staggering!

Interleaving

One potentially serious problem with digital recording is tape 'drop out,' this is a term used (in both analogue and digital recorders) to describe a momentary loss of intimate contact between tape and head during replay. In an analogue system this results in a short period of low level, distorted audio, annoying of course but not a total loss.

However, in a digital system the problem is far more serious, because dropouts result in the loss of a large chunk of data, causing a loud click at the output. To overcome this, consecutive signal data is not recorded in a sequential fashion but 'interleaved' by jumbling up the data samples and distributing them in a different order across the recording medium. In this way, any dropout that may occur will contain a mixture of various non-consecutive bits of data, making error correction a little easier. If a very serious loss of data occurred, many systems will simply mute the output. Whilst this gets over the loud click problem the result is effectively a short period of silence!

Digital Recording Parameters and Considerations

In order for a digital recording system to equal and better the performance of its analogue equivalent, it must meet certain expectations and conform with certain parameters.

Bandwidth

Firstly, the full bandwidth for use in audio is considered to be 20kHz and is normally quoted as 20Hz to 20kHz. As we know this figure is based around the nominal frequency range of the human ear. This 20kHz bandwidth is actually quite comprehensive and takes account of those with the most sensitive hearing – young people! It's a sad fact however, that from the moment we are born our hearing response deteriorates; by mid-life we can consider ourselves fortunate if we can hear anything above 15kHz or so.

However, our professional digital systems must be able to cope with the full audio bandwidth of 20kHz if they are to realise their full potential.

Dynamic Range

The dynamic range of an audio system can be described as the usable range in dB between the quietest signal at one end of the scale, and the loudest signal at the other end, before the onset of distortion.

A good quality mixing desk, for example, is likely to have a noise floor of say –72dBu, with maximum headroom of perhaps 18dB above 0 level. Therefore the dynamic range could be quoted as 90dB, and a digital recorder will need to have a dynamic range of something approaching this figure at least if high quality (acceptable?) results are to be obtained.

Compatibility

Quite simply compatibility is vital, a tape mastered on one machine must be able to be replayed on another machine at another location without the need to resort to any form of fiddling or bodging to make the transfer complete. This means that a certain amount of co-operation between manufacturers is required and standards such as tape dimensions, sampling frequencies, track format, etc., must be agreed and adhered to. In the main this seems to be the case, and let's face it, any manufacturer who produces a system with odd ball sampling rates or non-compatible tape sizes will be left out in the cold!

Advantage . . . Digital!

One major advantage of digital recording is the fact that, as the audio signal is represented simply by a mass of binary numbers, coded groups of 1s and 0s, it is in theory possible to copy this pattern and thus the audio itself, an unlimited number of times without the degradation of quality so apparent in similar analogue systems. The beauty of digital storage in general – which could include anything from sounds, images or the written word – is that the accuracy of the information merely depends on the correct numbers being retrieved, not the quality of the media in which the numbers were stored. If this is done successfully, then nothing is added and nothing is taken away from the original during the copying process. (Perhaps this is what is wrong with the CD critics mentioned earlier – they are simply missing all the background noise and other 'fluffy' bits they are normally used to, hence it sounds unnatural!)

Unfortunately the record companies have also realised the implications of the benefits of perfect copies, and are now forcing manufacturers to equip recorders for the domestic market with a system known as SCMS (Serial Copy Management System). In basic terms SCMS allows one digital copy only to be made from an original digital source such as CD or DAT, as during the copying process SCMS adds an inhibiting code to the data stream, and subsequent attempts to digitally copy the copy are not permitted.

Enterprisingly, some audio manufacturing specialists have developed and marketed a number of nifty little devices, which can be used to strip out or add the nasty SCMS inhibiting code when making tape transfers in the digital domain!

The quality of a digital recording is generally not affected by, and therefore independent of, the recording head and medium; this is borne out by the fact that it is now possible to record almost full bandwidth stereo music on a simple (but very high density) floppy disk! Further advantages over analogue include a total absence of wow and flutter type problems, with very low noise, distortion and crosstalk elements. Add to this the sort of track identification and timing information that can be laid down alongside the audio tracks, and digital recording techniques look pretty impressive!

Digital Formats

Perhaps the most familiar of early digital recording format was the PCM system based around a video recorder and an A-to-D, D-to-A conversion unit (Analogue to Digital, Digital to Analogue).

Sony developed the PCM F1/701 systems to be used in conjunction with a Betamax VCR. The F1 was aimed at the domestic market, bringing digital audio into the home for very reasonable cost, whilst the F701 was intended for the more professional user and thus could be mounted in a rack.

Another variation, the PCM 1610/1630, was used with U-matic format video recorders and was aimed at the serious professional user. Many master tapes for CDs were, and still are, produced using this type of system.

The PCM adaptor unit converted the incoming analogue audio signal into a coded digital format using either a 14- or 16-bit format, with added timing information and line/field sync pulses, and modulated the whole to follow the pattern of a video waveform. This composite signal is then simply sent to the input of a VCR and striped onto the video tape in the conventional manner.

A novel feature of PCM, by way of coincidence, is the system's inherent ability to produce a video image of the digital audio on a monitor screen! This is easily accomplished by connecting the video output of the VCR to a monitor tuned to the appropriate channel. Viewing the data has limited value for most people, but it is quite interesting to actually see the digits fly by with the music!

R-DAT

Now firmly established in the home studio and professional environments, and considered by the likes of Sony to be a mature format, R-DAT (Rotating-head Digital Audio Tape), now simply referred to as DAT, is proving to be an easy to use and flexible recording medium. However, in common with several other current digital formats, there is the editing problem. Traditional analogue tape cut editing is not possible with DAT, but reasonable results can be achieved by 'dub editing,' although this can be frustrating and time consuming. The other method of editing such material is to download the data to a hard disc based system and edit it using

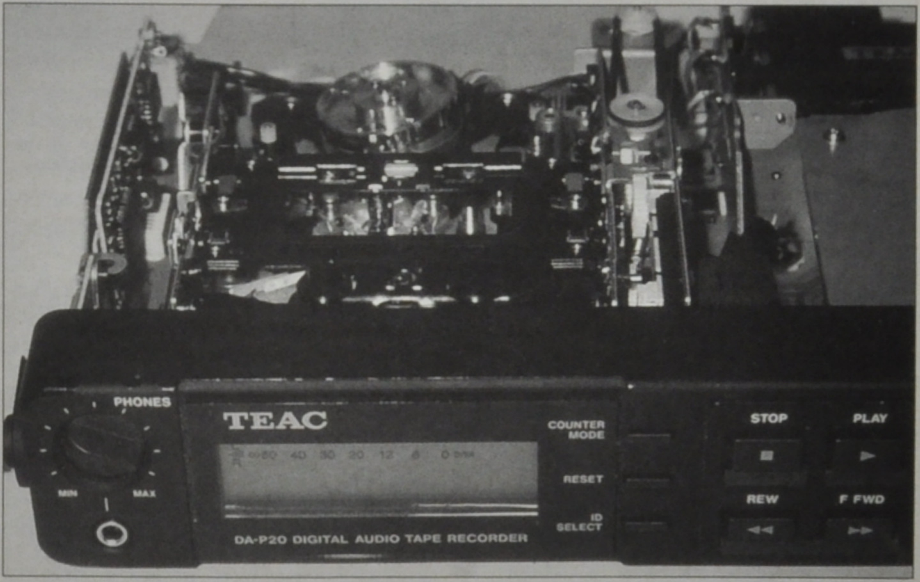


Photo 1. Internal view of a TEAC DAT recorder, the rotating head-drum assembly can be seen at the rear of the transport mechanism.

Photo 2. Examples of studio and portable DAT recorders.

a proprietary software package. There are various versions available, but none come very cheaply!

DAT uses the 48kHz sampling frequency as standard and can thus accommodate full bandwidth audio. All the usual benefits apply, such as the absence of tape hiss, dynamic range, etc., and the recording quality is really very good. As mentioned earlier, some machines offer a choice of sampling rates, such as 32kHz for extended long play recordings, or 44·1kHz for direct CD mastering.

A cursory glance inside a DAT recorder (Photo 1) reveals a mechanism similar to that of a VCR, albeit on a reduced scale. Indeed, tape transport functions and systems are similar to familiar tape loading, a rotating drum containing the heads and helical scanning of the tape. VCR machines use a 180° tape wrap around the drum which can be slow and rather difficult to load, and presents a problem when fast spooling is required. DAT simplifies this situation by using only a 90° tape wrap. This obviously allows easier tape loading and unloading, giving faster tape access and spooling operations. In theory, such a complex mechanism in this small scale should create all manner of reliability problems, but I must say that of the DAT recorders I have worked with this is not the case. All credit to the manufacturers!

There is now a vast range of DAT machines on the market, with facilities ranging from the basic to the outrageously complex and priced accordingly. The more comprehensive machines will offer a full choice of sampling rates and some have 'useful' editing facilities.

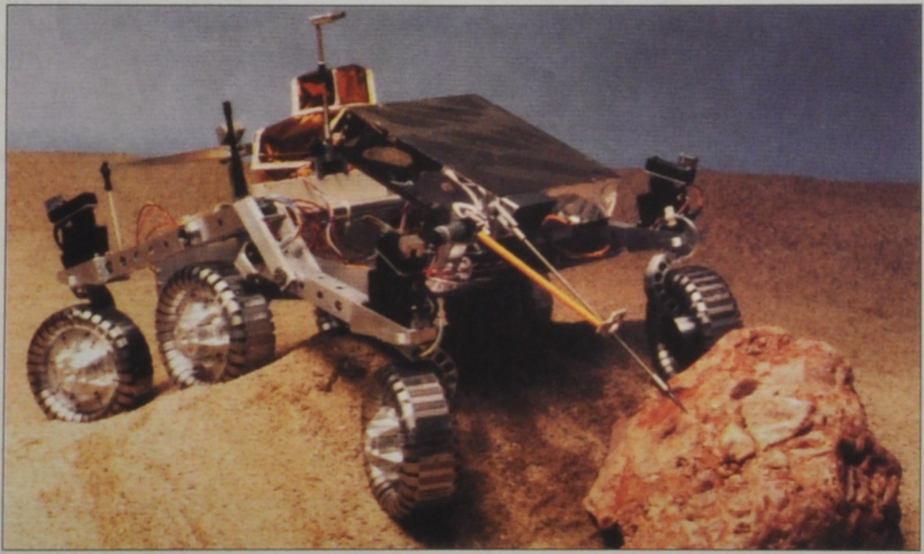
Photo 2 shows two nice DAT machines; the portable unit on top of the Sony studio machine is the TEAC DA-P20. It has around two hours of life from the rechargeable batteries, quality XLR input connectors, a reasonable mic input stage and a good reliability factor.

Having personally seen three of these machines in more or less constant use over the last year or so, I can say that they have certainly given a good return for a very modest investment.

The DA-P20 has won many friends since its launch a year or so ago, and, with only a few bad reports, is finding its way into many a location recordist's and radio journalist's duffle bag!

Next month we shall continue the digital theme by looking at disc based audio systems and multitrack digital recorders.

Mysterious Mars *continued from page 52*



Above: Photo 14. Rocky IV is one of a range of vehicles being tested for possible future missions to Mars where survey craft will explore the terrain more extensively around landing sites

Future Unmanned NASA Mars Missions

It is likely that the next NASA Mars mission will be the Mars Environment Survey Pathfinder. This will involve an orbiter and lander with a micro-rover of a type such as Rocky IV shown in Photo 14. Such a vehicle would allow the robot controlled rover to traverse terrain and avoid rocks and other hazards by an on-board intelligent 'behaviour control' system. (See Photo 14.)

Future Manned Mars Missions

At present the USA, with its commitment to the Shuttle project, has no 'super rocket' to lift into low Earth orbit in a realistic time, the large payload of around 500 tons of craft that would likely be needed for a manned mission. However, Soviet spacetechnology developed the vast 'Energiya' rocket which can lift individual payloads of around 120 tons into space and so assemble a craft in low orbit relatively rapidly.

One critical aspect of any planned mission, is whether 'rocket braking', or 'air braking', would be used to slow the craft down to be captured by Mars gravity. If 'air braking' is used, then a reduced payload of fuel would be required for the mission. Unfortunately, in the present climate of economic uncertainty among the world's economies, it is less likely that the announcement of a manned Mars mission is imminent. However, it seems certain that developments in technology up to the turn of the century will make aspects of the mission more affordable, and fundamental developments in new methods of propulsion may speed progress rapidly. The mission is also likely to be a co-operative one.

Over the years many proposals and plans have been put forward to 'tame' Mars – to regenerate the atmosphere and colonise the cold dusty planet. This work is both highly complex and highly speculative, but even now key groups of scientists are working towards making such dreams a reality. We are at the same point in time now perhaps as Columbus was at the court of Spain, begging for funds to sail west and find another route to India. As we all know, what he discovered came as a surprise to everybody and the world has been a different place ever since. Can history repeat itself?

Conclusion

The Viking lander mission was a spectacular success which revolutionised our understanding of the red planet. Mars has suddenly been brought close to planet Earth – it is no longer a mysterious speck of light in the night sky. Just as on Earth we are always learning more and more about the Earth and finding there is more and more knowledge to be obtained – so it is likely to be with Mars – discovery will be endless – but certainly exciting.

Acknowledgment

Photos reproduced by kind permission of, and copyright ©1993, National Aeronautics and Space Administration/Jet Propulsion Laboratory.

Further reading: *Mars: The Next Step*, A. E. Smith, Adam Hilger.

Valve TECHNOLOGY

A Practical Guide- PART SEVEN

by Graham Dixey C.Eng., M.I.E.E.

IN the final part of this series, we conclude last month's discussions on practical audio amplifier systems with the final link in the chain between pick-up and loudspeaker – the power output stage.

The previous amplifier stages have been concerned with producing a faithful replica of the input signal, but at a larger voltage amplitude. The function of the output stage is rather different and certainly more demanding. Because it requires work to drive the speech coil of a loudspeaker, and because work equates to power when we introduce the time element, the output stage must produce large excursions of *current* as well as voltage – and it must do so with the minimum amount of distortion being introduced. This means that the output valves must be capable of passing large current flows, which implies a heavy emission of electrons from the cathode surface in the first place. There are two factors that limit the amount of current that a valve can carry. They are:

(a) the surface area of the cathode capable of emitting electrons, coupled with the power input to the heater.

(b) the amount of heat that can be dissipated at the anode without causing degradation of the valve's performance, e.g., the emission of gases from the surface, which would seriously impair the operation of the valve by causing collisions between the gas molecules and the electrons in transit; excessive heat could also cause failure of the anode structure.

It is obvious from the above points that valves intended for high power applications (using the word 'high' in a relative sense, since one man's watt is another's kilowatt!) must have larger electrodes than those intended just for voltage amplification.

Triodes versus Pentodes

These two types are obvious contenders for the role of output valve; for the moment we will lump beam tetrodes in with pentodes. What we need to consider is how well each type of valve will be able to handle the task, given the rather stringent requirements that apply. Let us consider triodes first.

If the characteristics were absolutely linear and parallel, no amplitude distortion at all would result. Both half-cycles of the signal input would produce equal swings at the output, each being a faithful copy of the input.

The mutual (grid) characteristics for triodes tend to be both linear and parallel, which means that swings of the signal voltage along these characteristics should not cause too much distortion in the output (we won't, at the moment, quantify how much distortion is tolerable), so this is a plus point for the triode. On the other side of the coin, however, is the low gain of the triode. This means that, for a given output signal amplitude, the input signal has to be fairly large if the stage is to be driven fully. At the same time the triode also takes a great deal of current from the HT supply, so is not very economical in terms of power consumption (when compared with its amplifying capability).

The type of amplitude distortion that the triode does produce is largely second harmonic. Thus, an input signal at, say, 400Hz would have, after amplification, a significant amount of an 800Hz component also. This fact is, as we shall see later, not as serious as it might at first appear, since it is relatively easy to reduce this type of distortion to acceptable proportions.

Looking at the pentode now, and bearing in mind some of the deficits listed above for the triode, one advantage that we can call to mind immediately is going to be its higher voltage gain, allowing the use of a smaller input signal in order to obtain a given output. Also, it takes less HT current, and so is more economical with supply power than the triode. However, its mutual characteristics are not as linear or as parallel as those of the triode, though it is possible to compensate for this deficiency.

As far as harmonic distortion is concerned, the dominant harmonic produced here is the third harmonic. Eliminating this is not as easy as getting rid of even order harmonics: 2nd, 4th, etc. One point of comparison that can be made with triodes, that we shall see is significant, is the value of the anode slope resistance, r_a. In triodes this is quite low, whereas in pentodes it is by comparison generally extremely high.

The Triode Output Stage

Any valve amplifier, being an active device that is delivering a signal to a load, can be considered in a general case to be a generator. Any generator cannot avoid having an internal resistance, and the value of this internal resistance will determine the optimum value of load impedance into which the generator can deliver its maximum power. For valves, the internal resistance is the parameter r_a, this being the reciprocal of the slope of the output characteristics, as we have seen in Part One and Part Two, and so is quite clearly the output resistance of the valve when feeding a load.

The *maximum power transfer theorem* states that 'a generator delivers maximum power to a load when the source resistance of the generator equals the load resistance'. Before anyone reaches for pen and paper to tell me that I am wrong, let me just add that this theorem as stated applies when the load is resistive. If the load is reactive then maximum power is transferred to the load when the load impedance has a value that is equal to the *conjugate* of the generator impedance. If the word conjugate isn't understood, don't worry about it; it comes from complex algebra, which I have no intention of going into here!

Figure 1 shows the valve represented as a generator. Figure 1(a) shows the triode (it could equally well be a pentode) with an input signal V_g, a load R_L in the anode circuit and the internal resistance r_a. The grid bias voltage is represented by a battery, and since this voltage is DC Figure 1(b) shows the equivalent circuit which can be used to analyse the performance of the amplifier. This comprises three components: a voltage generator μVg, which represents the valve action and two resistances: r_a, the generator internal resistance; and R_L, the load resistance. In the specific case of the valve, whether triode or pentode (in theory at least), the maximum power will be transferred to the load when the latter is equal to the r_a of the valve. This raises a problem immediately.

The load on an audio output stage is the speech coil of the loudspeaker. It is totally impracticable to wind such a speech coil so that it has an impedance anything like that of the r_a of even a triode valve, which will be of the order of

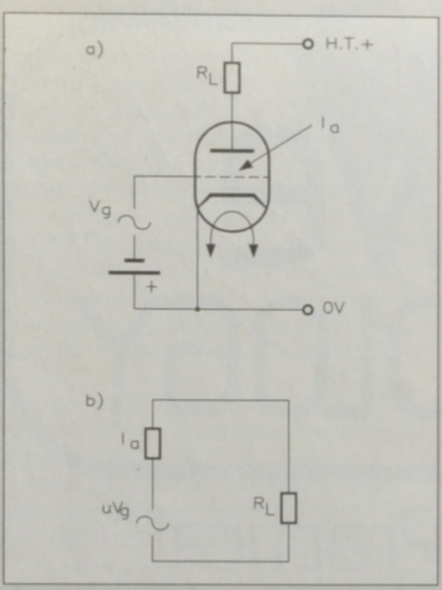


Figure 1. The valve as a generator; (a) actual triode circuit (without bias components) and (b) the AC equivalent circuit.

thousands of ohms! A practical value for the speech coil impedance is unlikely to be more than a few tens of ohms (eight ohms (8Ω) is a common nominal value). From this it is quite obvious that it is impracticable, in the case of valves, to connect the speech coil directly into the anode circuit of the output stage as the load. There are other considerations that make this undesirable anyway, but the above argument, on the grounds of load and source impedances, should make it clear why this course of action cannot be undertaken.

The Output Transformer

The answer is to use an output transformer with a step-down turns ratio. The required ratio '*n*' can be calculated from a simple formula, which is as follows:

$$n = \sqrt{\frac{\text{Load required by valve}}{\text{Resistance of speech coil}}}$$

Notice that the above formula says *load required by valve* and not actually the valve's r_a. This is because the load presented to the valve by the loudspeaker, through the transformer, is not resistive and it has been found in practice that the load that the valve needs to see is approximately equal to twice the r_a of the valve.

As an example, if the triode in question had an r_a of 8,000Ω and the speech coil resistance was 16Ω (using convenient figures for ease), then twice r_a is 16,000Ω and the turns ratio needed is equal to $\sqrt{1,000}$, which is approximately 33:1.

The penalty that one has to pay by making the effective triode load equal to twice the valve's r_a is an increase in the drive voltage required for full output.

Design of output transformers for quality audio reproduction requires great care. In particular, the primary inductance must be as high as possible (necessitating a bulky transformer) if it is to offer a constant impedance to the valve at all frequencies of interest. Modern cores are not made of 'ordinary' electrical steel as may be found in a mains transformer, but of a higher quality, purer stuff with superior magnetic performance; this also makes it possible to keep the bulk down to reasonable proportions, certainly modern examples are a good deal smaller than their early equivalents.

Other factors such as self-capacitance and leakage inductance must also be optimised if reproduction at the high frequency end of the spectrum is not to suffer. This is usually achieved by *not* winding the former in the 'normal' way like you would with a mains transformer. Instead, both primary and secondary windings are split up into sections *and* interleaved with each other; some of these arrangements can be quite complex and, to go really 'over the top', one layout incorporates a split bobbin, where the order of the layers on one half are reversed on the other half. Add to this a choice of secondary taps for different speaker impedances, and it can be appreciated that manufacture can be extremely labour intensive, and, hence, valve output transformers can cost a small fortune if you want genuine Hi-Fi quality. For more information on the subject, see the small book *Coil Design and Construction Manual* by B. B. Babani (available from Maplin, Code RH53H, Price £2.50) which came out as a first edition in 1960, and gives detailed guidelines on how to make your own. We wouldn't recommend designing and making your own output transformer however; there are, fortunately, still a few competent manufacturers around.

Tetrodes and Pentodes

In contrast to the triode, both of these types of valve have extremely high values of r_a that require careful matching to the loudspeaker impedance. The rule regarding triodes does not work in these cases, and it has been found that these valves work best when they see an effective anode load that is between one-third and one-sixth of their r_a value. Care is required in the design of output stages using such valves since, otherwise, they can generate an excessive amount of distortion. In general, the safest technique is to choose the load value which is recommended by the maker of the valve.

Although the beam tetrode may often be considered as the equivalent to a pentode (especially since they are alternative answers to the same problem of the interelectrode capacitance C_{ag}), there are significant differences due to their different modes of operation. One of these differences is the type of amplitude distortion that each introduces into the amplified signal.

In the case of pentodes, the distortion is principally third harmonic with only a little second harmonic; this is the opposite to the beam tetrode, where mostly second harmonic distortion is produced. Thus, in terms of harmonic distortion, beam tetrodes behave more like triodes.

Push-Pull Amplification

There are several ways of approaching the design of valve power output stages:

(a) Single-ended, where the output transformer is in the anode circuit.

(b) Parallel operation, where two or more valves are connected in parallel in order to boost the power output, the output transformer being again in the common anode circuit.

(c) Push-pull operation where two valves (or sets of paralleled valves) are driven alternately by the input signal, each valve having half of the primary winding of the output transformer in series with its anode, the centre tap of this transformer being connected to the HT supply positive line.

We can dismiss both (a) and (b) immediately on the grounds that, since the primary winding carries the full anode current in one direction only, its core would have to be excessively large or specially constructed in order to avoid saturation arising from the quiescent DC. Again the *Coil Design and Construction Manual* shows how this is

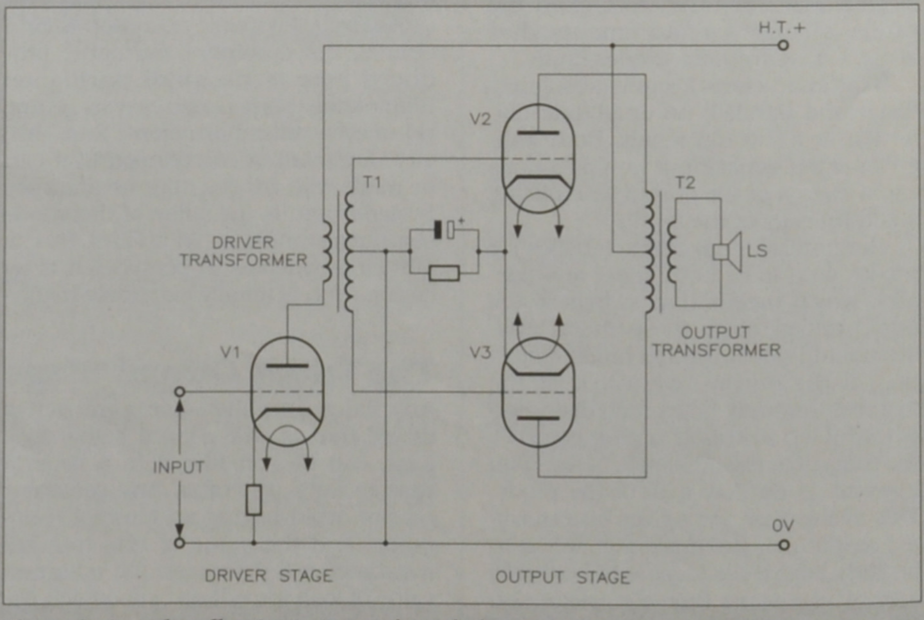


Figure 2. A push-pull output stage using triodes.

done; the common arrangement is where the magnetic circuit is effectively broken by introducing a thin layer of waxed paper or similar to separate the core into independent stacks of 'E' and 'I' sections. The gap reduces the core's sensitivity to DC, yet allows alternating magnetic lines of force to pass through. LF response is critically linked to the choice of gap spacing, so tolerances must be tight. Many consumer quality radiograms and record players *et al* used this type of output stage, but it is not worthy of serious consideration, especially as the type of harmonic distortion introduced by the output valve(s) cannot be reduced by this type of connection.

However, in the case of (c), push-pull operation, the DC anode currents flow in *equal and opposite* directions in the half-primary windings, and so their fluxes cancel out. Saturation is thus avoided, even with relatively small cores, the core size now being dictated by the consideration given above, of providing a constant load at all frequencies. The second advantage that arises from the push-pull connection is the cancellation of all even order harmonics. Figure 2 shows the arrangement of one possible type of push-pull output stage.

Valve V1 is the driver stage and valves V2 and V3 form the push-pull output stage. The phase-splitting action is performed here by the use of a driver transformer T1, in which the secondary winding is centre-tapped to 0V and so provides a pair of equal, anti-phase voltages to the grids of the output valves as well as DC bias. With no signal input to the driver stage, both output valves draw only their quiescent current, and this flows in opposite directions in the half-primaries of the output transformer T2.

When a signal is being amplified by V1, both ends of the driver transformer T1 are at opposite potentials with respect to the centre-tap, the latter being connected to the cathodes of both output valves via the cathode bias components R1 and C1. Thus, as the grid of one output valve is being driven in one direction, say positively, the grid of the other output valve will be driven in the opposite direction, in this case negatively. The terms *positively* and *negatively* are here used in a relative sense, since whether the signal voltages are actually positive or negative *with respect to 0V* will depend upon the way in which the output valves are biased. The classes of bias possible with output valves are illustrated by the mutual characteristic shown in Figure 3.

Classes of Bias

These are more commonly used to describe 'classes of amplifiers'. Taking Class A first of all, this is the bias method commonly employed with most single-ended amplifiers, i.e. not wired in push-pull. The valve is biased to the mid-point of the characteristic such that the quiescent anode current is large, and the signal swings cause equal changes in this current for both half-cycles. Distortion is minimised, but efficiency is low because of the high DC power input required to obtain a given AC power output. The available AC power output is also reduced, because the valve is contributing to both positive and negative half-cycles of the output signal, and having to do it within its available total signal excursions.

If, instead, the valve is biased to the point of projected cut-off, the valve is then operating in Class B. The quiescent anode current is extremely low, giving very high efficiency, but the amount of distortion introduced is high, making this mode unsuitable for quality reproduction. Its main application is in public address systems where quality is less important than cost.

A compromise class of bias then is Class AB, where the bias point lies between those for A and B. This gives an improvement in efficiency and possible power output over Class A, with better quality than can be obtained with Class B. Class AB actually divides into two sub-classes, depending upon how hard the grids are driven. In Class AB1, drive is restrained so as not to cause grid current to flow; in Class AB2, grid drive is increased and grid current flows at the peaks of the positive half-cycles.

Finally, in Class C operation, the grids are biased well beyond cut-off and are driven very hard in order to make anode current flow in short pulses, just at the peaks of the positive signal half-cycles. This type of bias is restricted to radio-frequency operation, where the pulses of current merely excite a resonant circuit in order to produce a full sinusoidal output. So now you know!

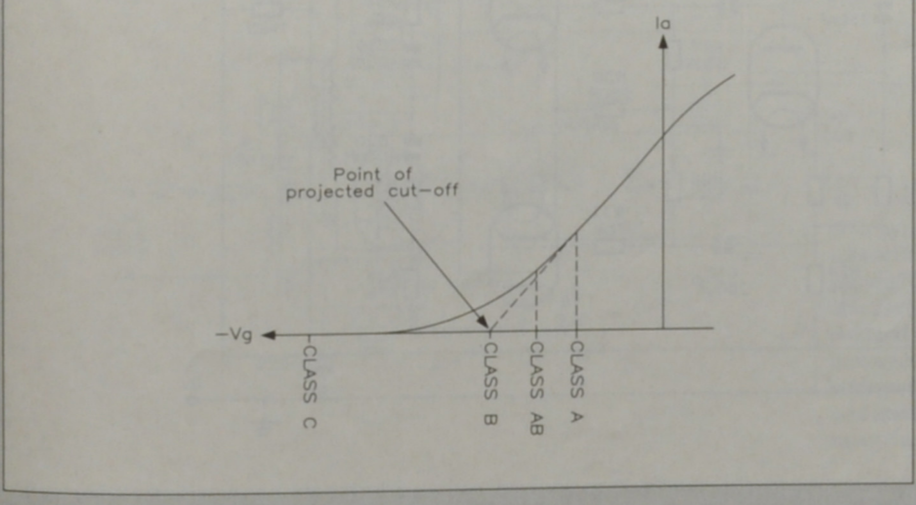


Figure 3. Classes of bias.

Harmonic Cancellation

Because of the fundamental way in which push-pull output stages work, the signal currents in the output valves flow in *opposite* directions in the output transformer's *secondary* winding. The magnetic flux that links with the secondary winding of this transformer induces voltages that are *additive* in this secondary. Thus, a positive half-cycle developed in valve V2 at one instant causes a corresponding voltage to be developed in the secondary winding; this is followed by a negative half-cycle produced by valve V3, which also induces a similar voltage in the secondary winding. As a result, the secondary voltage appears as a continuous voltage, compounded from the successive efforts of the two push-pull output valves working separately but in co-operation.

However, any even order harmonics, 2nd, 4th, 6th, etc., generated by the output valves cause *opposing* magnetic fluxes in the primary winding which, consequently, cancel out. No even order harmonics appear in the secondary winding. This is a major advantage of push-pull operation. It is obvious that this is of more significance when triodes or beam tetrodes are used, since this is the type of harmonic distortion that these valves generate. This somewhat dampens the popular idea that the main characteristic of such amplifiers is that they generate lots of 2nd order harmonic distortion!

Value of Anode Load for the Output Stage

The actual value of the anode load in push-pull operation is not the same as that calculated for single-ended operation. Again, the best bet will be the figure provided by the valve maker, since this will have been computed to give the minimum amount of odd order harmonic distortion. In pentodes, it is third harmonic distortion that is the major type, and it is possible to minimise this by a suitable choice of load. In fact, it is essential to do this, since push-pull operation does not result in any reduction in the odd order harmonic content. It has been found that reducing the value of anode load substantially below the nominal value reduces third harmonic distortion and increases second harmonic distortion, the latter then of course being cancelled by the push-pull connection.

Negative Feedback

It is possible to write a book on this subject; many have already done so and I have no intention of adding to the published material. Suffice it to say that it is a matter of great importance in the design of audio amplifiers, of *any* type. Thus, the theory is not specific to valve amplifiers. Its benefits are well-known in reducing distortion of all types, in giving gain stability and in coping with the resonance problems of loudspeakers. That is all that need be said about it here.

Examples of Hi-Fi Audio Amplifiers

We shall now have a look at a few audio amplifier circuits which will illustrate the various approaches that designers have adopted in the past.

The Garner 10W Main Amplifier

The first of these is shown in Figure 4 and was designed by Major H. H. Garner in the early 1950s. It doesn't have any pretensions to exceptional performance but is, nonetheless, a creditable performer according to G. A. Briggs, who tested it exhaustively at the time. It was paired with a preamplifier, which had the obligatory bass and treble controls as well as input switching for pick-up and radio, and compensation for LP and 78rpm records.

The circuit is fairly simple and the line-up is quite conventional for those days. (The 'line-up' was the collective expression used for all the valves.) No miniature valves were used; these were still a little way off in time for general use. The output valves were the popular 6L6s and these were somewhat underrun. The distortion figures may not seem exciting but were seen as being adequate for the purpose. At an output power of 5W, the THD was 0·8%, which rose to 1·5% at 10W output.

The pentode first stage, V3, included overall negative feedback from the output transformer secondary winding. This could be varied between zero and 22dB of NFB (Negative FeedBack). Apart from the fact that this varies the sensitivity of the amplifier, no justification was offered for this arrangement. The points that were made were as follows.

(a) Since the 6L6 output valves made no great demands upon their input drive, a concertina phase-splitter was considered adequate, with balancing of the biphase outputs being achieved simply by matching the values of load resistors R24 and R26.

(b) Because of the high input impedance of the phase-splitter, it was possible to use a pentode first stage to give both high gain and good top response.

A 10W Amplifier for Mobile Public Address

The circuit of Figure 5 shows an amplifier that appeared in the American magazine *Radio-Electronics* in March 1957. This was published in response to a letter from a reader who wanted a power amplifier both for his FM tuner and for mobile PA requirements. Since it had to be mobile, it couldn't use a mains supply, so a feature of the design was a vibrator pack, to convert the low level vehicle DC (6V, no less) into the higher level HT required by the amplifier.

The first stage, V1, was a 6SJ7 pentode, used purely as a microphone preamplifier and giving enough gain to allow any high output, high impedance crystal or dynamic microphone to be used.

A separate tuner input was provided that tapped directly into the grid of one half of the double triode V2a. Here we see a choice offered between the older and larger 6SL7-GT valve and one of the newer all-glass miniatures, the 12AX7 (ECC83). The output valve is another popular choice of the day, the 6V6; or a 6AQ5 could be used instead. The phase splitter is of the paraphase type with V2a as the first stage and V2b as the second stage. Anode loads are 150k and these feed the purely conventional output stage comprising pentodes V3 and V4. Overall NFB was taken from the 8Ω tapping on the output transformer secondary winding to the cathode of V2a. A grid signal for V2b is contrived by tapping the grid leak resistor chain for V3.

The Craftsman C-500

In the May 1956 issue of *Radio-Electronics* there appeared a circuit for a typical 'Williamson' amplifier, the 'Craftsman C-500', shown here in Figure 6. For those not in the know, Williamson was a famous name at the time in the field of Hi-Fi amplifiers and belonged to D. T. N. Williamson who was employed as an engineer with the British firm of Ferranti. His 'Craftsman C-500' amplifier uses a pair of KT66s, which were very popular high power valves in those days. Although they are actually beam pentodes, they were connected as triodes by wiring the screen grid to the anode via a 100Ω resistor. (The use of the KT66 in triode mode is validated by applications data; not all pentodes and tetrodes may automatically be connected up this way.)

Note also the circuit symbols used for them. Do you remember in Part Four I mentioned that often beam tetrodes are given pentode symbols in circuits, whereas the beam tetrode version should really be used for clarity? Although the KT66 is classified as a pentode, it has beam forming plates in place of a suppressor grid, and is practically indistinguishable from a beam tetrode in construction.

In this circuit the first stage, V1a, is a preamplifier, whose output drives a concertina phase splitter V1b, thus neatly putting both stages into one double triode. Note also that, as was

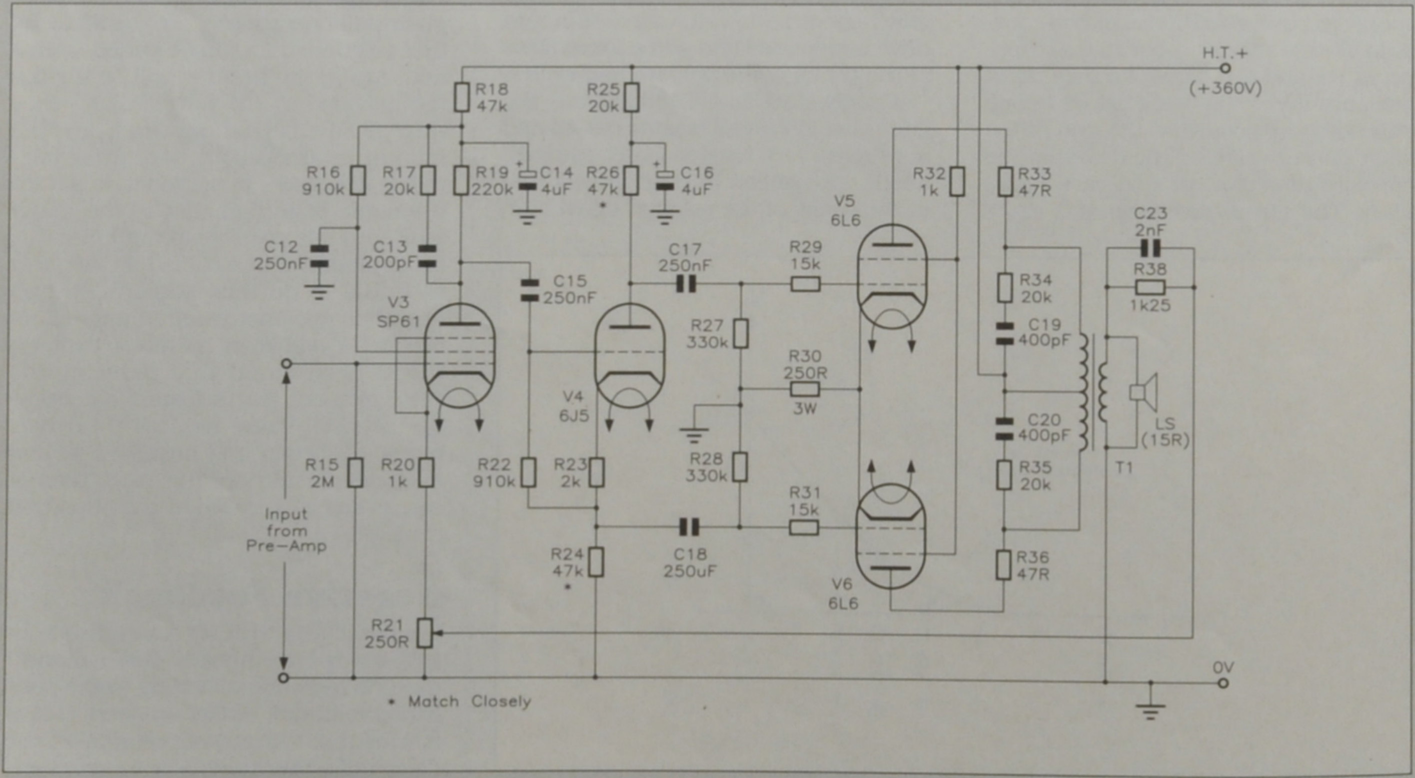


Figure 4. The Garner 10W Main Amplifier.

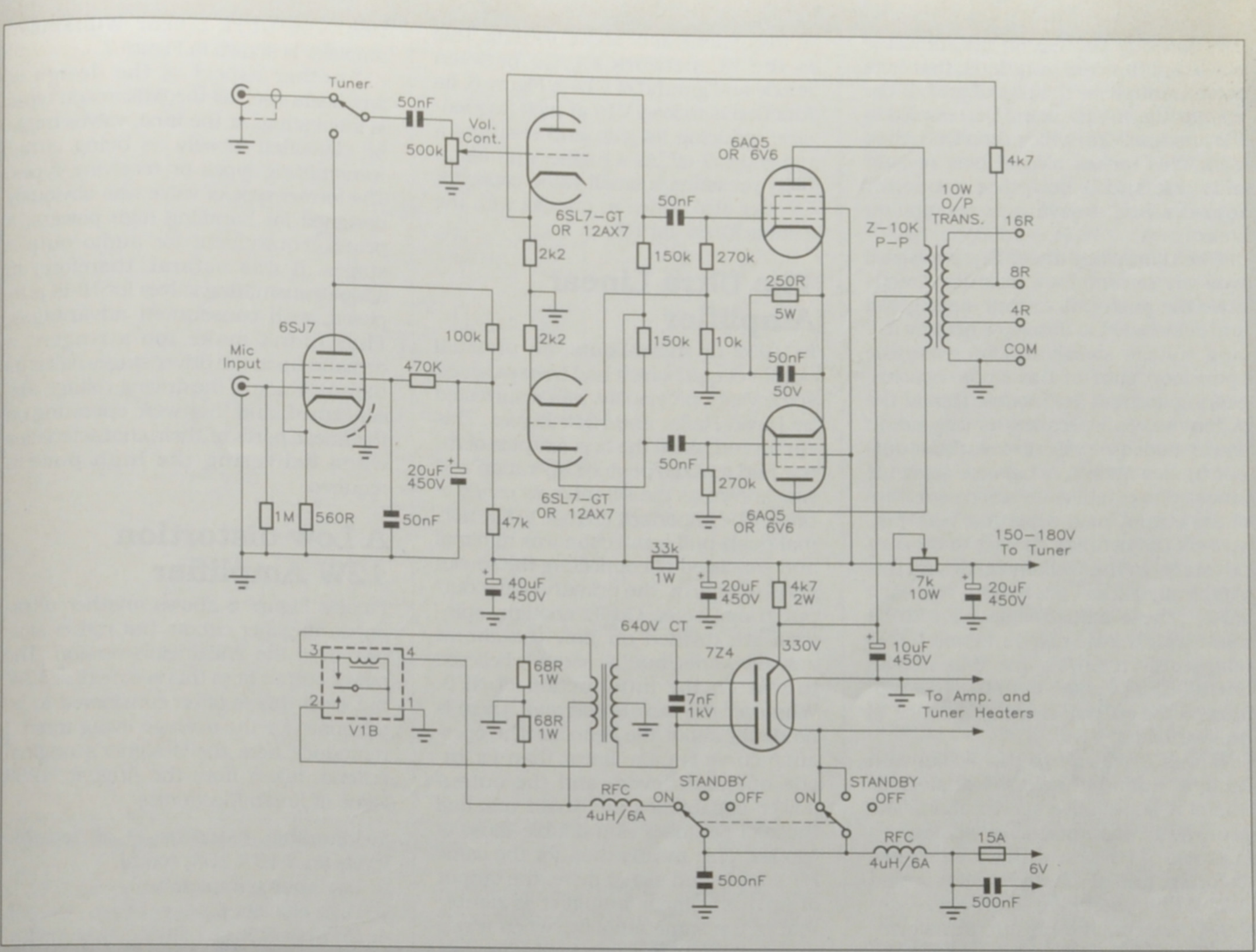


Figure 5. A 10W Mobile Public Address Amplifier.

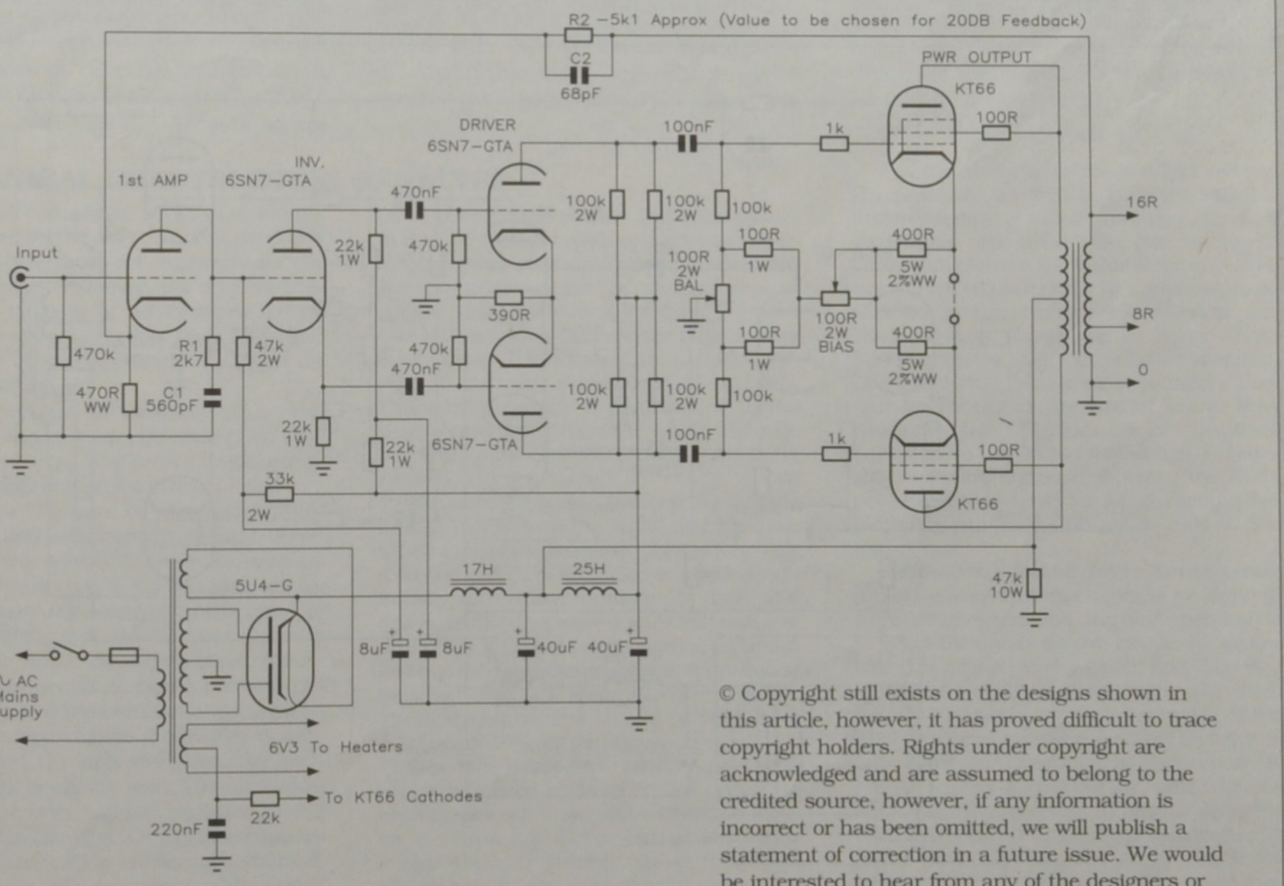


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Figure 6. The Craftsman C-500 Williamson Amplifier.

mentioned in Part Six on the subject of phase splitter configurations, that here is an example of the signal grid of the splitter stage, V1b, being DC coupled to the anode of V1a, which then DC biases V1b. This makes a local bias resistor network and a coupling capacitor unnecessary, a saving in component count.

The third stage driver is a push-pull type whose antiphase outputs directly drive the push-pull output stage grids, and is included to develop a healthy driving voltage swing and increase the open loop gain of the whole system, bearing in mind the modest gain of the output valves, operating as they are in triode mode (see discussion about output triodes above). A 'balance' preset is provided to equalise the anode currents of the output pair, while the 'bias' preset sets the net bias current in the output stage. In the Williamson design this is typically 125mA (62 to 63mA for each valve). These adjustments have to be made with the aid of a multimeter after temporarily removing the link shown. Overall NFB is taken from the 16Ω tapping on the output transformer back to the cathode of V1a.

It was a feature of the Williamson designs that the output transformer was of a superlative specification. The bandwidth was enormous, sometimes in excess of 100kHz, with extremely low distortion and of massive size. It is said that Williamson amplifiers were designed around the output transformers. The wide bandwidth introduced instability problems, however, in the presence of NFB. It was possible to alleviate this by including a bypass network within the loop that was only effective at frequencies at or above 100kHz. This is the RC network R1/C1 between anode and ground of V1a in Figure 6. Its function is to load V1a at high frequencies, reducing its gain and ensuring a top end roll-off. As a further anti-instability measure, a small value capacitor C2 was also added in parallel with the feedback resistor R2.

The Ultra Linear Amplifier

In 1952 or thereabouts, an unusual output circuit, which had been patented some years previously, was resurrected by David Hafler and Herb Keroes. This circuit combined the best features of triode and tetrode/pentode operation and was known as the *Ultra-Linear configuration.* The important change to the normal push-pull connection was minimal and consisted of connecting the screen grids to taps on the primary of the output transformer. Oddly enough, opinions are divided on how the circuit actually works, but the secret is believed to rest on the introduction of NFB. Whatever the *modus operandi,* there is no doubt about the benefits. The operating curve is more linear than for triode operation even, and the output power capabilities are about one-half those of pentodes and double those of triodes. This means that, for the same HT supply and signal drive, the output of an ultra-linear amplifier is double that of the same amplifier when triode connected. In fact, distortion at low levels is reduced as is the phase-shift at high frequencies. This makes it possible to increase the degree of NFB without incurring any further instability penalties. The Ultra-Linear Williamson amplifier is shown in Figure 7.

Another aspect of the design of amplifiers such as the Williamson types is interesting. At the time, valves might be classified loosely as being either transmitting types or receiving types. The former type of valve was obviously designed for handling high powers, a prime requirement for audio output stages. It was natural, therefore, to adopt transmitting valves for Hi-Fi purposes, with consequent advantages. They didn't make too stringent a demand upon the driver stages as far as the amplitude of the driving voltage was concerned, and they were operating on the linear parts of their characteristics when delivering the high powers required.

A Low-distortion 12W Amplifier

Finally, Figure 8 shows another ultra-linear amplifier circuit, but rather simpler than the Williamson version. The power output from this is a modest 12W, but even this is often considered to be adequate for the average living room. I reproduce here the designer's original criteria, taken from the August, 1958 issue of *Radio-Electronics.*

1. Inaudible distortion at all feasible levels (in a 10 x 15ft. room).
2. Low source impedance.
3. High efficiency.
4. Best possible stability characteristics.
5. Hum and noise below audibility (under specified conditions).

The designer concentrated most of his efforts on consideration of the degree

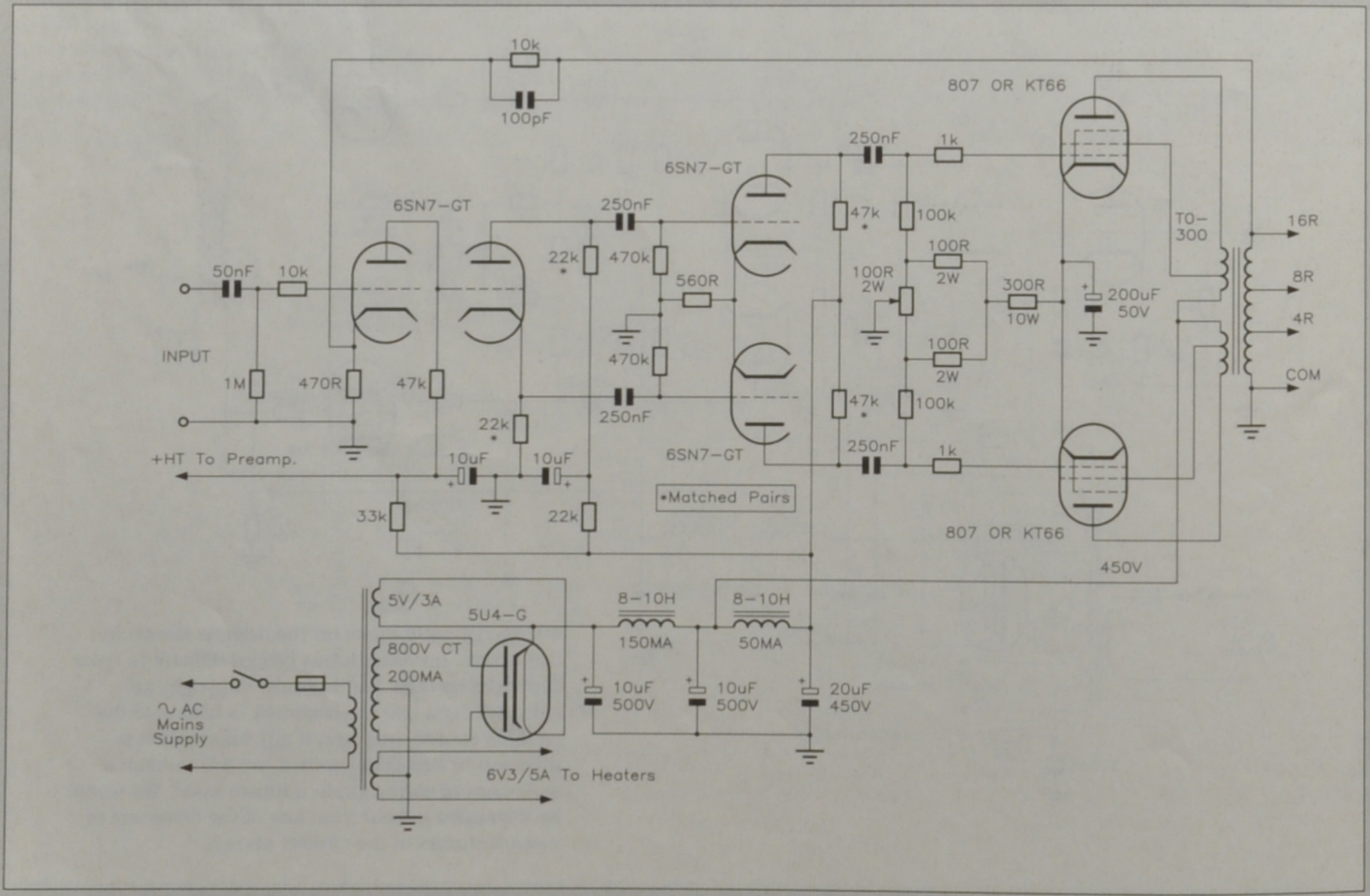


Figure 7. The Williamson Ultra-Linear Amplifier.

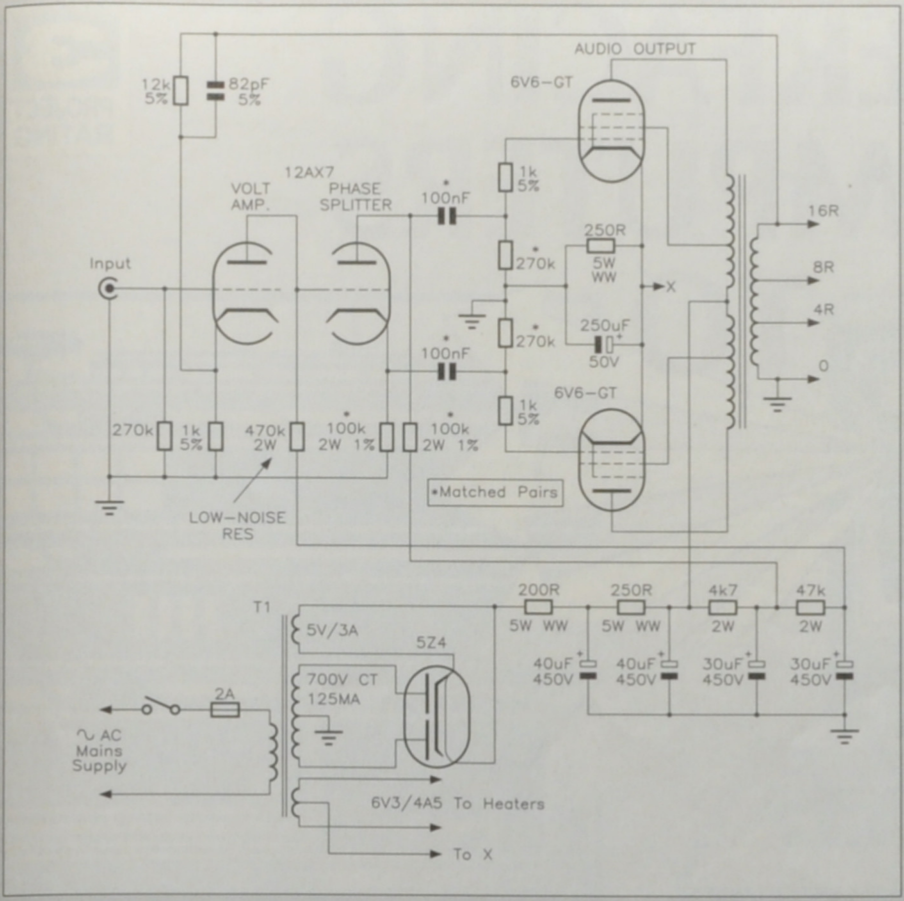


Figure 8. Design for an ultra-linear 12W amplifier.

of NFB needed to meet his criteria 1 to 4 above, and opted for the ultra-linear mode of operation, using a pair of 6V6s. To obtain this type of operation with these valves requires the output transformer primary winding to be tapped at 25% on each side of the centre-tap. The choice of output transformer, from what was on the market at the time, fell on the Acrosound TO-310, which had a rating of 10W over the bandwidth 20Hz to 30kHz, and 20W over the reduced-bandwidth of 30Hz to 20kHz, the latter being adequate for good reproduction.

The circuit itself uses a 12AX7 (ECC83) double triode, with one section, V1a, being a voltage amplifier directly coupled to a concertina phase-splitter. This gave a number of advantages.

The DC coupling eliminates one stage of capacitive coupling which gives greater frequency stability. Placing the phase splitter directly before the output stage (which is possible due to the low drive requirements of 6V6s) eliminated the hum frequently resulting from the large potential difference between the heater and the unbypassed cathode of V1b, being amplified by a further push-pull driver stage. The anode load of the voltage amplifier acts as the grid leak of the phase splitter, thus allowing the voltage amplifier to work into a very high impedance, so that high gain with low distortion are obtained from the first stage of amplification.

Efforts were made to improve the performance by matching pairs of resistors and some capacitors (if possible) to within 1% of each other. These are indicated on the circuit diagram. It seems, from the comments made upon completion and testing, that the amplifier's performance lived up to expectations.

That just about concludes this series on Valve Technology, which has been restricted to audio applications only, and this is now one of the few fields left where valves still survive – we haven't even mentioned radio, TV, instrumentation and industrial applications, which of course at one time valves had to cater for also! The only other area where valves are still in common use is for radio transmitters (a very large, high voltage, high power triode operating in class C).

We hope you have found the series both interesting and informative, and that it has answered a lot of questions you may have had about these devices. You may now be sufficiently better informed to try some experiments of your own. Elsewhere in this issue you will find details for Maplin's own valve power amplifier project, which closely resembles Mullard's '520' ultra-linear design of the late 1950s and early 60s. Happy metal-bashing!

MECHANICAL CONSTRUCTION OF VALVES

The 'Valve Technology' series has mainly concentrated on the electrical characteristics of valves, since these are important for the circuit designer. However, the manufacture of valves, though of no concern to the designer or user, is equally fascinating and as a subject warrants inclusion in an industrial museum!

It has become obvious that glass was chosen for the envelope because of its ease of manufacture, material consistency, strength under compression to contain a vacuum and its tolerance to wide temperature variations, and was, logically enough, developed from the light bulb. It is also obvious that the plug-in type of valve is almost universal for easy replacement in the event of failure or ageing (but also because it's not a good idea to solder directly to glass embedded metal connections), hence the base pin connections and the use of chassis sockets.

In those types where the insides can be easily viewed through the glass, the construction will be clearly seen. The valve components are spot-welded together into a support structure which typically comprises vertical rods carried in horizontal sections of mica or similar. However, getting this assembly into the glass envelope is NOT the same as putting a model ship in a bottle!

In fact the envelope begins its life as two parts, the envelope proper, and a glass base. In B9A valves, this base also carries the plug-in connection pins which need an involved glass-to-metal seal and bonding process to prevent leaks (in octal valves these are solid core lead-out wires because the plug-in base is separate). These bases are usually supplied to the valve assembler prefabricated. The valve assembly is spot-welded to the base connections, then the whole slid into the envelope whereupon the two glass parts are joined by gas flame.

The envelope is then pumped to evacuate it. B9A valves have the small diameter exit tube on top of the envelope, octal valves have it in the centre of the base at the bottom. Initially mechanical pumping is used, but this is unable to achieve a sufficient vacuum on its own, so at the point when no more can be removed by this method the operation is switched over to a mercury vapour pump. Ideally the air content should be reduced to an order of 10^{-7} atmospheres.

When the number of remaining gas molecules has been reduced to the necessary scarcity, the exit tube can be closed by melting it with a gas flame. This action leaves behind the ever present pip on the top of B9A valves. In the case of octal valves, the plastic base carrying the plug pins would be glued on and the lead-out wires soldered into the hollow pins.

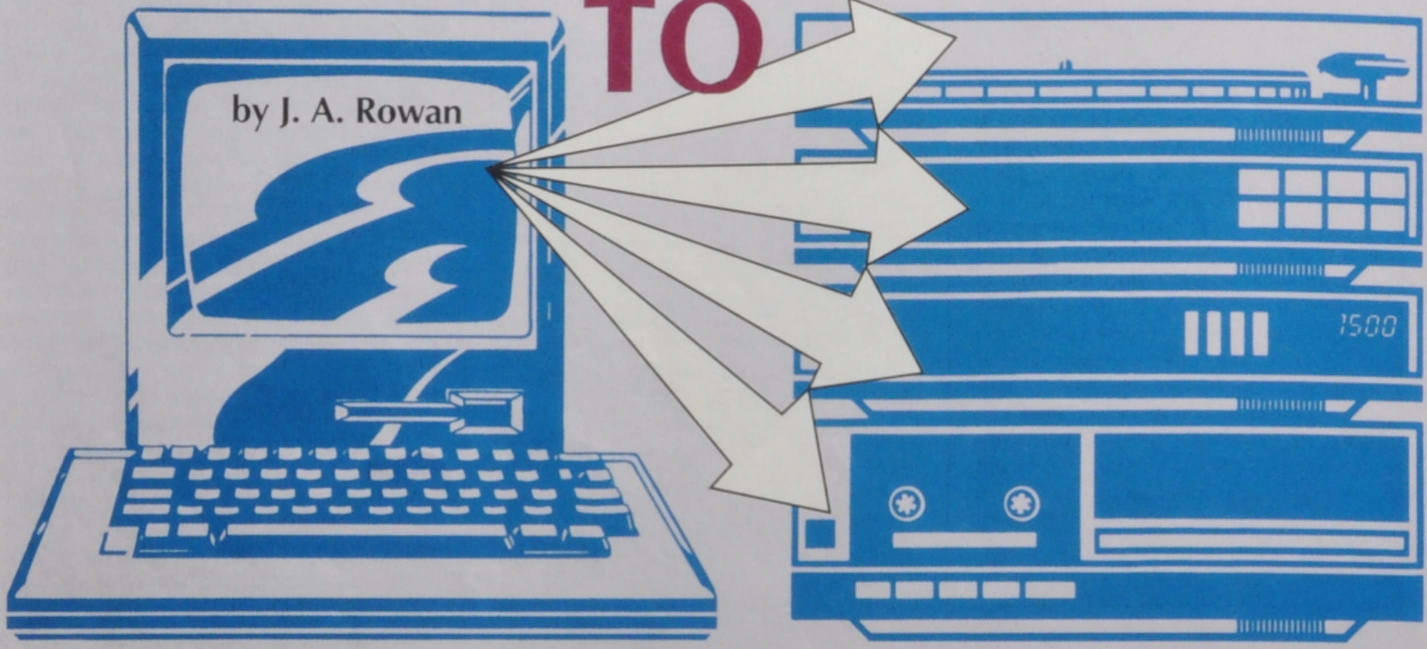
But the device is not ready to be used yet. On examining a valve's innards you will also find metal rings or other curiously redundant structures, with what looks like patches of chromium plate on the inside of the envelope, none of which apparently has anything to do with the way the valve works when in use. You'd be right. These are the 'getter rings', and the silvery stuff is the getter material. The getter ring form is most common, they can be found at the top of many B9A envelopes, but variations are not unusual. For example the GZ34 rectifier has its getter ring encircling its base, whereas the EL34 power pentode has two small rectangular platforms supported on single rods at the top.

On assembly this structure carries a compound embedded in channels or depressions. After evacuation, the final operation is to insert the finished valve into an RF heater which is aligned to the getter ring. The ring is heated to boil off the compound, which deposits an oxide layer on the inside of the glass in the vicinity of the ring. The oxide is only stable in a vacuum, as its property is one of quickly absorbing air molecules. As such then, the material not only depletes the last remaining air further, but also traps any gases that may be given off by electrodes while in use. A case where the glass has cracked and let all the air in is easy to spot. The getter material will have turned completely chalky white.

INTERFACING COMPUTERS TO CONSUMER ELECTRONICS

by J. A. Rowan

3
PROJECT RATING



How many VCRs have you ever seen that cannot make timed recordings? That's what they're for, right? But how many audio cassette decks are there in existence with timed recording facilities?

APPLICATIONS

* FOR CONTROL OF DOMESTIC EQUIPMENT THAT DOES NOT HAVE A TIMER FUNCTION * GENERAL COMPUTER CONTROL SYSTEMS

The Main Problem

My interest in this subject started when Radio 4 began repeating old comedy shows at 11pm on Monday nights. Most mornings I have a six o'clock start, and I didn't really want to stay up late to listen to them. I could just wait until eleven and start my recorder, but I would only lay awake wondering what the show was about, and might as well have listened to it anyway. In the old days, you could put a cassette recorder into record mode with the power off, and plug it in to a time switch, at least if you didn't mind buying a new pinch roller now and then. Like most modern decks, however, my Denon DR-M07 is solenoid-operated, and uses light-touch switches and electronic logic. This, of course, makes remote control possible.

Of course, this system can be applied to any similar application. Elderly logic-controlled VCRs can now be given comprehensive timer-controlled facilities. Satellite receivers can be made to change channel in the same way that a modern VCR's tuner can when it changes event – conventionally, you're stuck to timer-recording one satellite channel which is limited when you bear in mind the increasing number available. Even a radio tuner could be adapted – I need not be limited to recording a Radio 4 programme when I go to bed!

The First Attempt

A quick lash-up was made one Sunday, using reed relays and my trusty old BBC B, to assemble a crude timed record facility. My old reeds were well beyond the drive capabilities of the Beeb's user port, so I had to use a large 18V power supply with drivers (for my Christmas tree lights, if you must know . . .) hooked up between the Beeb and the cassette deck. It worked, but there were several drawbacks. The real-time clock in the Beeb is an add-on, and doesn't keep very good time, so I had to set the clock on the day it was needed – no good if I wanted to record something while I was away for a week! More to the point, the Beeb has a plastic case and radiates like a spark-gap transmitter. Radio 4 and one or two other channels can just about crawl through my receiver while the Beeb is running, but only in mono – my choice of listening material was therefore somewhat limited! The Archimedes is much better-behaved, having a metal case, but alas has no user port. Besides, the huge antique reed relays, bulky power supply and anachronistic ribbon cable were a bit of a bodge. It would be much better all round to make use of the Archimedes serial port.

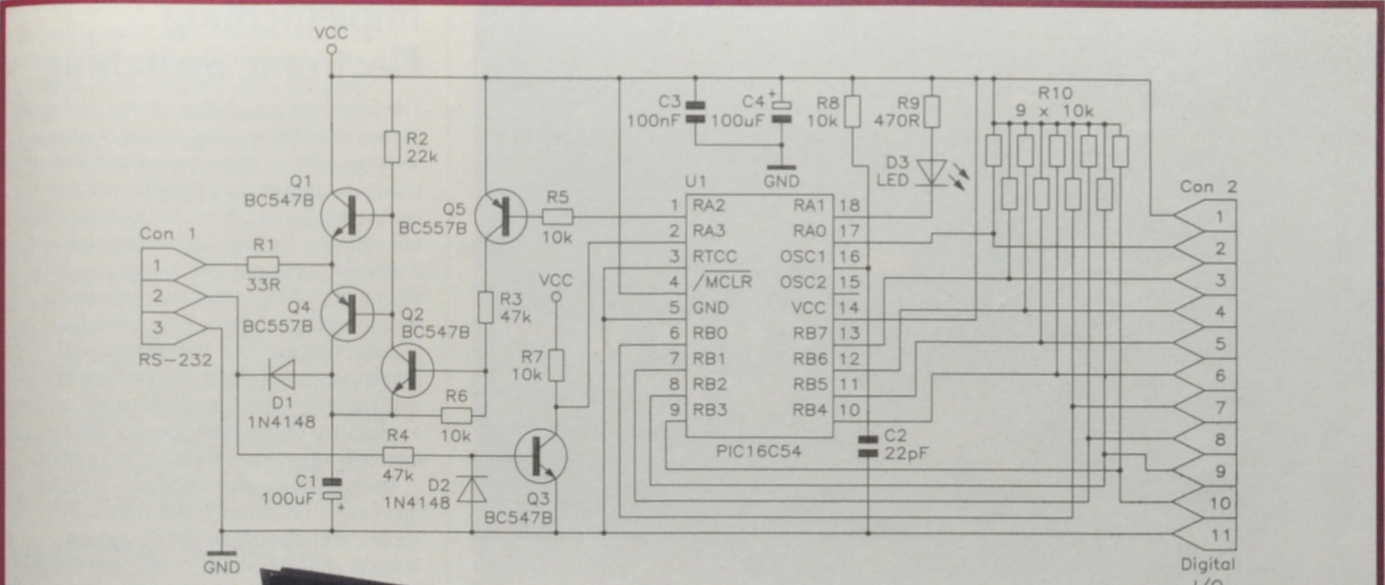
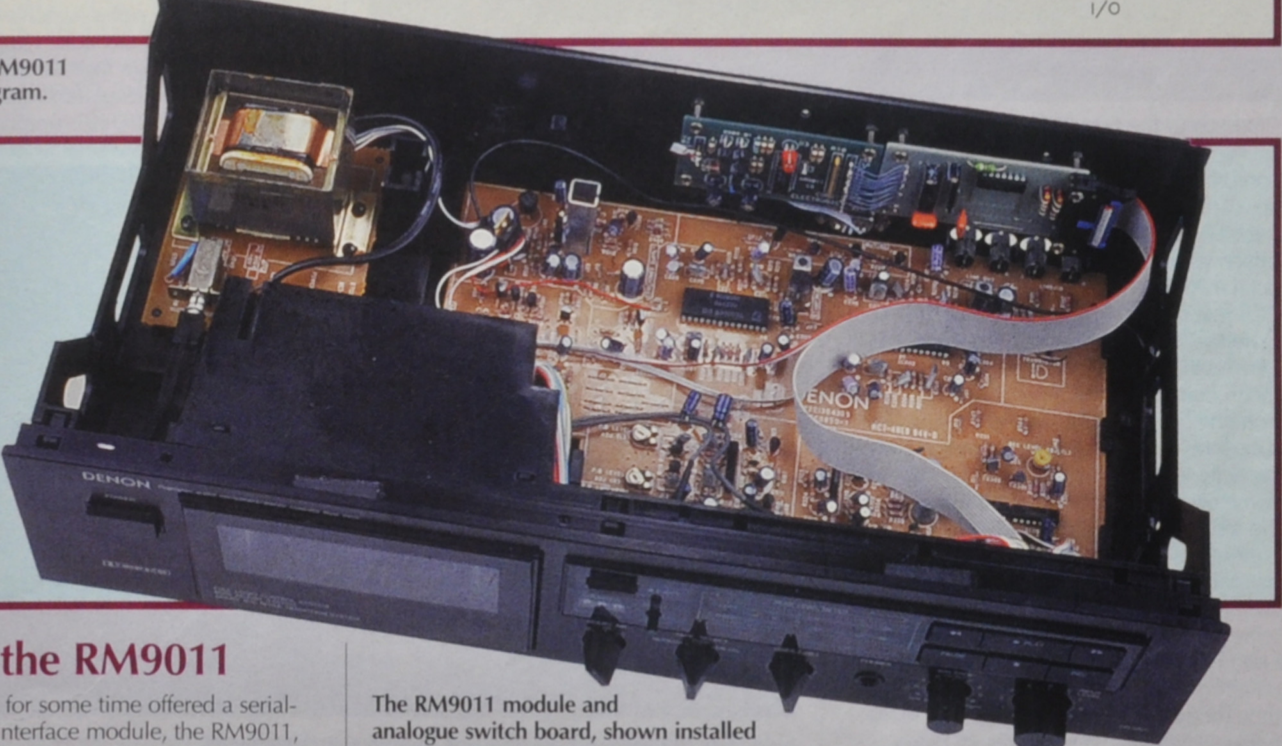


Figure 1. RM9011 circuit diagram.



The RM9011 module and analogue switch board, shown installed in a Denon DR-M07 cassette deck.

Enter the RM9011

Maplin has for some time offered a serial-to-parallel interface module, the RM9011, the circuit diagram of which is shown in Figure 1. This device was reviewed in the January 1992 copy of *Electronics* (Issue 49), and is also detailed in the 1994 catalogue. It took only a little thought to show that I couldn't build such a device for that price, and so I took the plunge and bought one. It can supply 10mA from each of the eight outputs, but even the smallest 5V relays draw that much. A born pessimist, I don't like running anything right on its limits. In this case, particularly, the component damaged would be the irreplaceable one (the PIC chip), requiring the purchase of a new module. So for driving even these small relays, a buffer is required, and the ULN2803A is the obvious choice. A problem immediately occurs: the RM9011 powers up with its lines programmed as inputs, naturally enough. Pull-up resistors are used to interface with TTL and so the lines are all high at power-up. The ULN2803A is an inverting buffer, and so all the relays would be initially on – something of an embarrassment! Even immediate reprogramming, as outputs, leaves the lines high, and they would have to be written to in order to set them low. If the cassette deck is ever used without the computer (i.e. most of the time), the deck would be somewhat

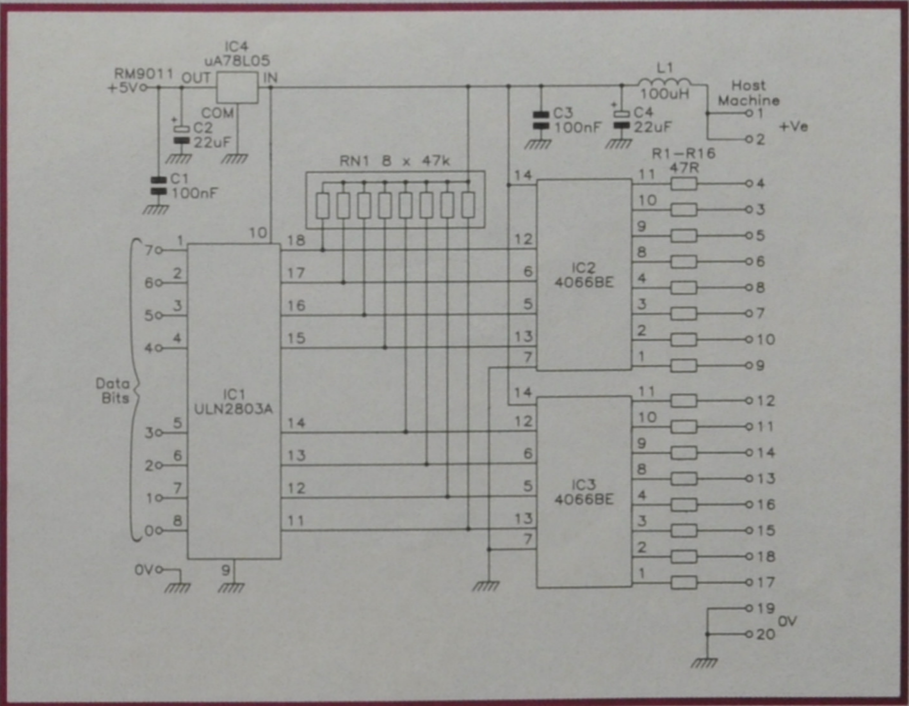
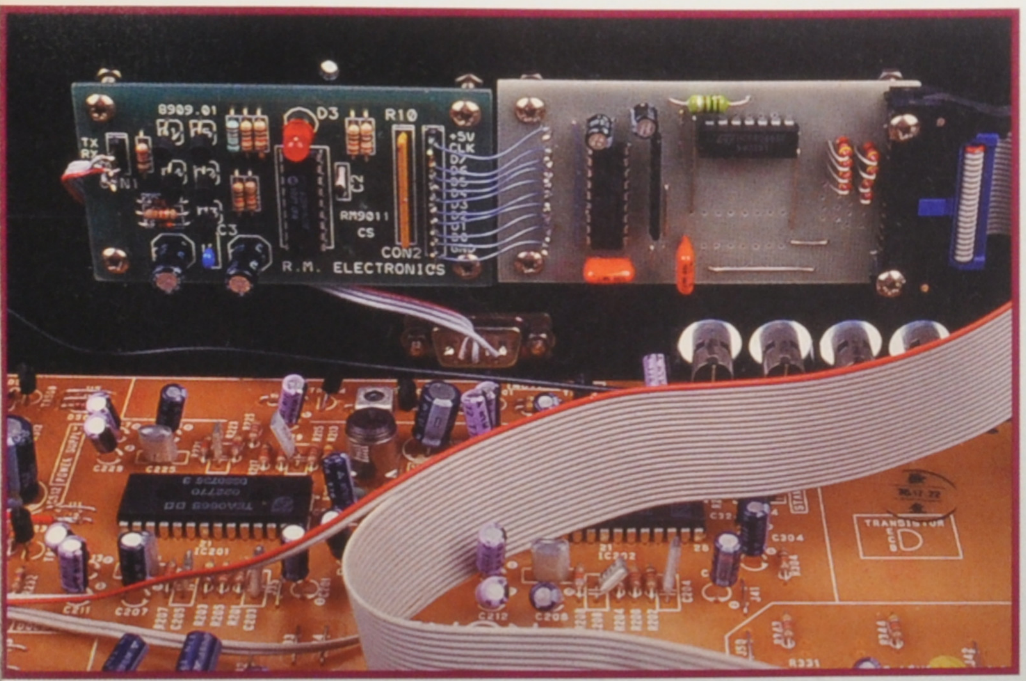


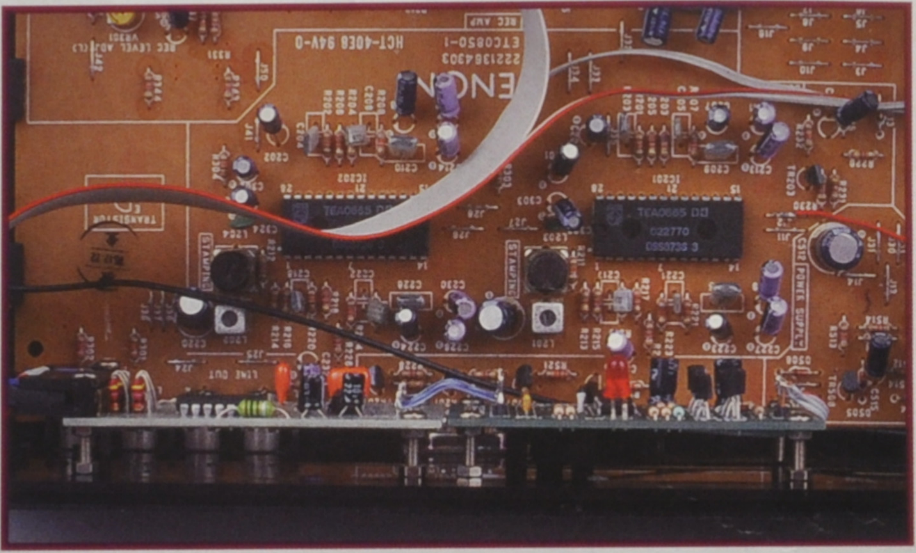
Figure 2. Analogue switch board circuit diagram.

confused as all of its control buttons would appear to be pushed at the same time! No, the ULN2803A is only useful with relays if driven via inverters, requiring a 74xx240 octal inverting buffer and a very messy PCB layout.

Relays have a further disadvantage. 10mA per relay may not seem like very much current, but I wanted to steal power from the host machine and something like a cassette deck may not have much spare capacity in its supply rails. If all eight relays come on even momentarily on power-up, the resulting drain could push a light-current power supply into shutdown. This naturally led me to investigate electronic switching. This needs a little care; a pair of relay contacts are isolated from everything else in the world, and can be used in parallel with a switch. What's more, little thought has to be given to what is actually being switched – within limits, of course.



Close-up of the two PCBs. The RS-232 interface 9-pin 'D' connector can be seen clearly.



Side-view of the two PCBs, showing mounting arrangements.

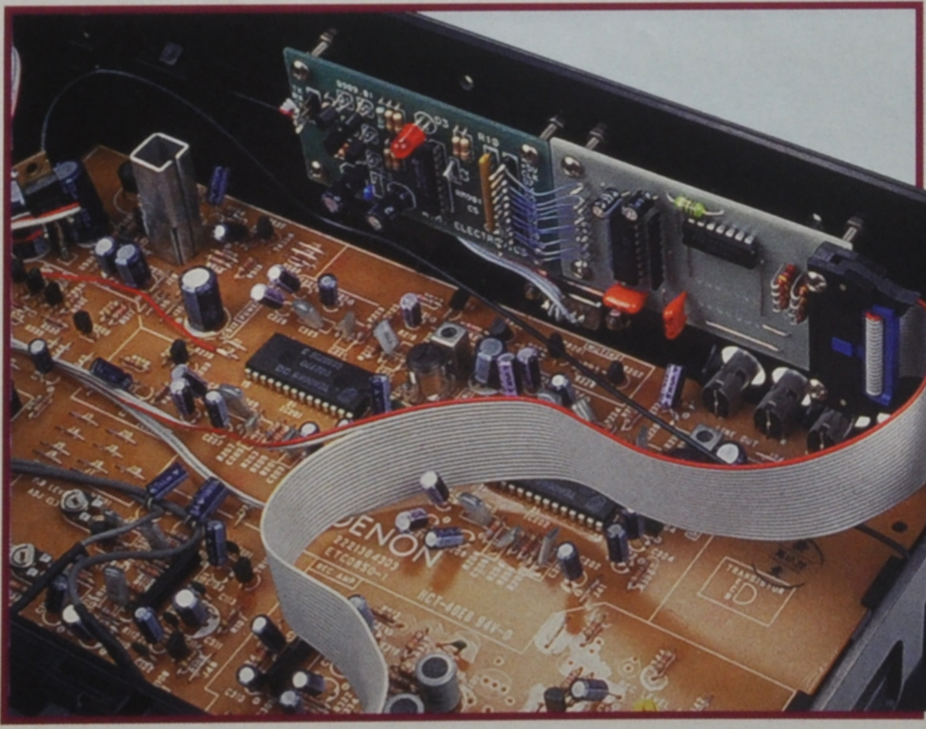
Implementing Electronic Switching

The final interface design, shown in Figure 2, uses 4066BE semiconductor analogue switches. These, however, are not isolated from their power rails, and the voltages being switched must not fall outside those rail voltages. Further, such a switch has a definite minimum 'on' resistance, and this must be low enough to operate the host machine's circuits. Out came the oscilloscope and box of resistors, and I determined that the front panel switch reading pulses went from 0V to 5V, and that a resistance of less than about 2·5kΩ would definitely operate all the switch functions.

The minimum resistance of a 4066BE quad switch is about 250Ω with a 5V supply, and that of the 74HC version is lower still. Even with small protection resistors in series, either switch will operate the front panel circuits quite happily. The 4066 requires a high logic level to close its switches, and this level must be the same as the V_{DD} voltage. This is no problem for the ULN2803A, which has open collectors and will therefore provide any level-shifting required, in this case to CMOS logic levels. It doesn't even need the extra inverters in this configuration. There will be a problem if your machine's switch-multiplexing circuit uses negative voltages, and a discrete transistor circuit will then have to be used to provide the correct logic level shifting.

If you need to shave operating currents to a minimum, use the ULN2801A, which does not have built-in base resistors. With the kind of collector currents used here, base drive resistors of a few hundred kilohms would be in order, and would avoid the 1·5mA drive current that is required for each ULN2803A input (5V supply). The PCB design will need to be modified, of course, but there is enough space for the extra base resistors on the board.

The 4066BE has some built-in static protection for its switches, which are basically FETs. There are diodes on each line to clamp voltages to V_{DD} and V_{SS}, but



Completed installation.

series resistors will increase the protection by limiting surge currents through the diodes. Static protection is not too important once all the switch lines are connected into the host machine, but before installation any unconnected CMOS line will be vulnerable. If the PCB will be assembled more than a few hours before installation, make up a shorting plug to ground the switch connections. For the same reason, any unused switches should be grounded. Severe damage to an unused switch may cause problems with the rest of the IC package. By the way, beware of the 4016, which is similar (but not identical) to the 4066. In the interests of lower leakage current in sampling applications, the 4016 has no diode protection on its switches. Use it if you must, but be very careful.

Analogue Switch Board Construction

Only the switch board needs to be built up, since the RM9011 is a pre-assembled module. Thanks to the simplicity of the circuit, a scrap of stripboard would suffice. As an alternative, the layout of Figure 3 could be used. If you are making your own PCB, 1·3mm holes should be drilled to accept the PCB pins.

The usual anti-static handling precautions should be taken with CMOS ICs, and it is recommended that sockets are used. In my version, only four individual switches were required (in parallel with the Record, Stop, Play and Pause keys), and so the second 4066BE device was not required. Perhaps tuner control could form the basis of future expansion?

PCB pins can be used for the various connections to and from the circuit. On the prototype, a right-angled 20-way IDC header plug was used for the switch outputs; the board design of Figure 3 will accommodate such a connector, although PCB pins will work.

The only other points to watch out for are RG1, the on-board 5V regulator, the electrolytic capacitors and the resistor array; these components are polarised. My Denon cassette machine already has a regulated 5V supply rail, and so RG1 was not required.

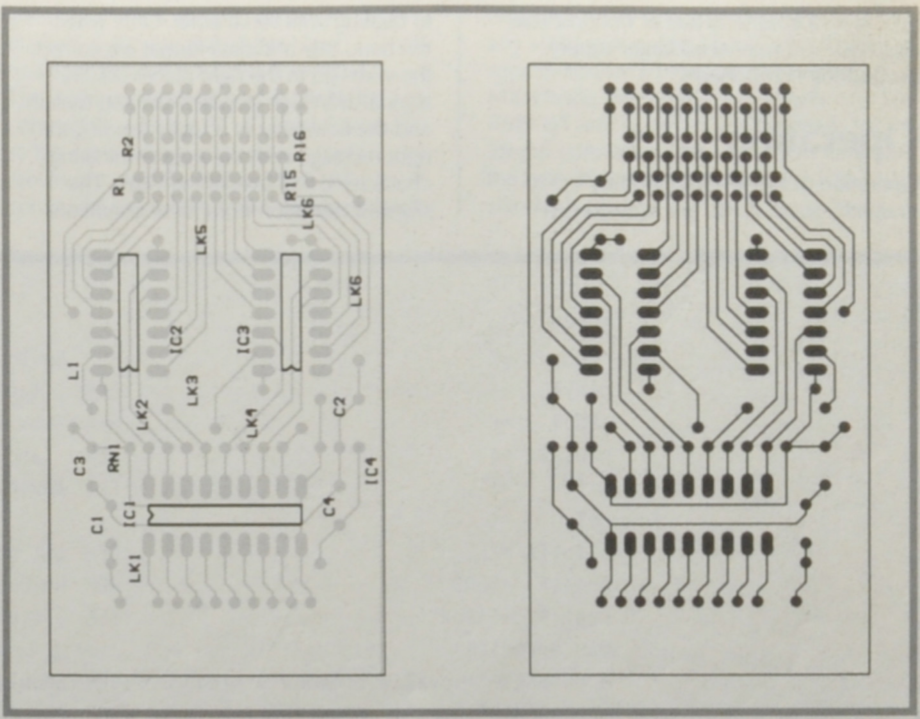


Figure 3. PCB legend and track.

Installation

The RM9011 module comes ready-assembled, requiring just a 5V supply; the wiring diagram of Figure 4 shows how its power can be derived from the switch PCB's on-board regulator. The switch PCB of Figure 3 is about the same size, and has the same fixing centres, so both boards can be stacked if necessary. As can be seen from Figure 4, the inputs to the switch PCB are pin-for-pin compatible with the RM9011, with a gap opposite the unused strobe output – this makes the two boards easy to link up with ribbon cable.

The IC of the RM9011 is a PIC chip. It's not exactly a high-speed CPU driving two or three dozen unterminated foot-long PCB tracks, but it may still radiate an unacceptable level of noise. Try placing it inside your cassette deck (most modern front-loaders have a lot of fresh air inside) and making some trial recordings with no input. Connect and disconnect the power supply to the module, listening carefully on playback for any changes in the background noise level. Try all possible combinations of noise reduction and tape types, since the bias level will change and may turn up an objectionable beat with one or more combinations. My deck seems quite relaxed in this respect, but if yours has problems you may need a metal case around the boards, or even to mount them outside the deck. The front panel switch connections will probably still be all

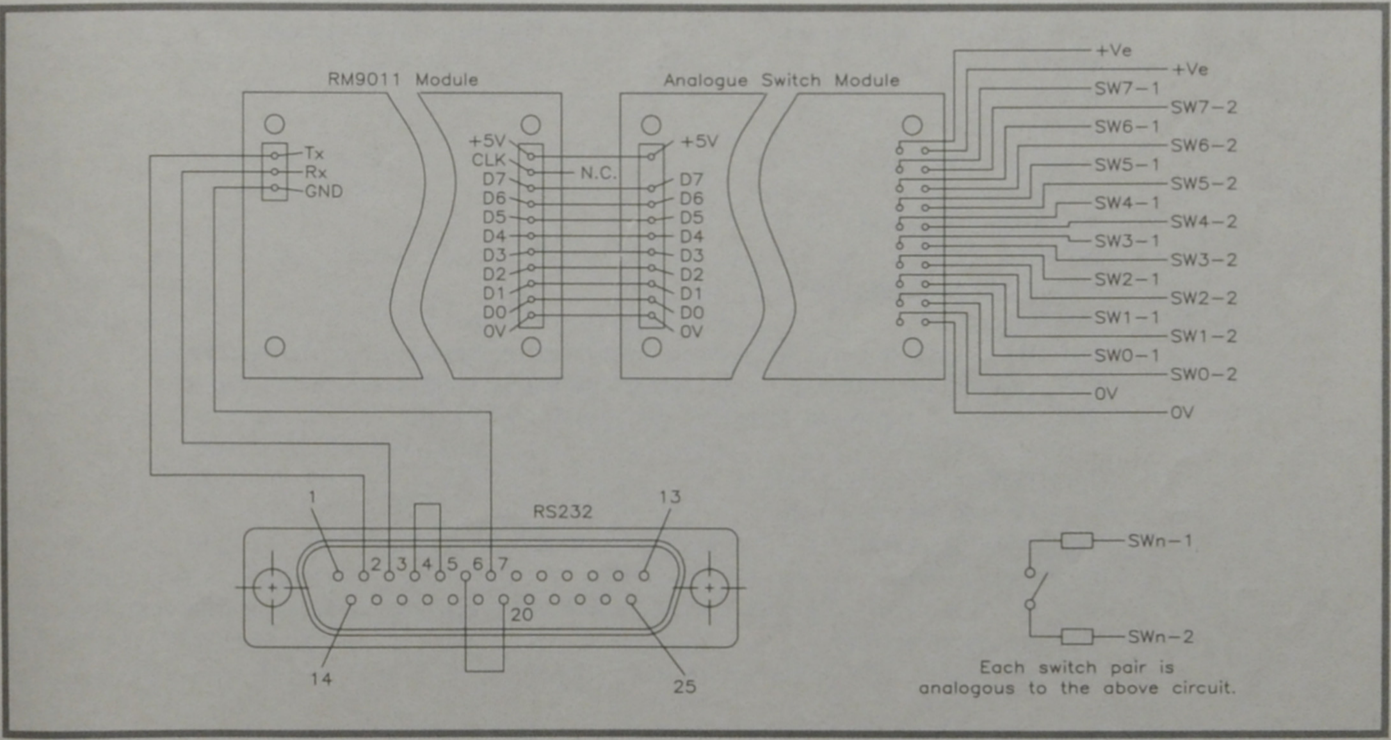


Figure 4. Wiring diagram.

right with a couple of feet of ribbon cable attached. You may need larger supply decoupling components.

Operation

Operation of the RM9011 is fairly straightforward, if you are accustomed to dealing with serial ports. Only when the baud rate and data format are correct, the wires go to the right places (RS232 standard? Which standard did you mean?) and the computer is actually sending the right message with the right terminating character(s) will everything work. The slightest deviation from these conditions will cause total failure, with no indication as to the kind of problem involved, or even whether any of the equipment concerned is working. An oscilloscope helps a bit, at least letting you know whether either or both machines are transmitting. The RM9011 will automatically sense which of several data formats and two common

```
DEFFNinit
 record% =7                             :REM  Switch connections between RM9011 and
 play%   =5                             :REM    tape deck. Either keep track of them
 stop%   =6                             :REM    or find them out afterwards by trial
 pause%  =4                             :REM    and error.
 off%    =1                             :REM  Inverting logic, remember
 on%     =0
 alloff% =255                           :REM  Let go of the button
 press%  =5000                          :REM  Hold the button for this long
 reply$  ="!ACK"                        :REM  Successful reply string from RM9011
 DIM error$(5)
 error$(1)=" Invalid command string"    :REM  Shouldn't happen...program error
 error$(2)=" Serial output buffer full" :REM  Check cable or conditions for transmission
                                        :REM   from computer serial port
 error$(3)=" RM9011 does not reply"     :REM  Tape deck turned on?
 error$(4)=" Invalid RM9011 reply"      :REM  Shouldn't happen
 error$(5)=" RM9011 returned error"     :REM  NACK received correctly from RM9011
 state%=stop%
 SYS"OS_SerialOp",5,4  TO ,oldRXbaud%   :REM  Receive  1200 baud:    save previous value
 SYS"OS_SerialOp",6,4  TO ,oldTXbaud%   :REM  Transmit 1200 baud          "        "
 SYS"OS_SerialOp",1,25 TO ,oldformat%   :REM  7 bit, 1 stop, even parity  "        "
 SYS"OS_Byte",2,0      TO ,oldstream%   :REM  Disable serial input        "        "
 SYS"OS_Byte",21,1                      :REM  Flush serial input buffer
 SYS"OS_Byte",21,2                      :REM  Flush serial output buffer
 SYS"OS_Byte",2,2                       :REM  Enable serial input
=FNconfig(0)                            :REM  Set all RM9011 bits to outputs
REM------------------------------------------------------------------------
DEFPROCtidy
 SYS"OS_SerialOp",5,oldRXbaud%          :REM  Restore original serial parameters
 SYS"OS_SerialOp",6,oldTXbaud%
 SYS"OS_SerialOp",1,oldformat%
 SYS"OS_Byte",21,1                      :REM  Flush serial input buffer
 SYS"OS_Byte",21,2                      :REM  Flush serial output buffer
 SYS"OS_Byte",2,oldstream%              :REM  Restore original stream(s)
ENDPROC
REM------------------------------------------------------------------------
DEFFNplay
=FNpushbutton(play%)
DEFFNpause
=FNpushbutton(pause%)
DEFFNstop
=FNpushbutton(stop%)
DEFFNrecord
REM  This function works with a deck that requires separate pressing of "record"
REM   and "play" buttons, in that order. Modify using FNbytewrite if your deck
REM   needs both pressed together.
  LOCAL failed%
  failed%=FNpushbutton(record%)
  IF failed% THEN =failed%
=FNpushbutton(play%)
DEFFNrecord_pause
REM  Modify if your deck does not go into record/pause just by pressing "record"
=FNpushbutton(record%)
REM------------------------------------------------------------------------
```

Listing 1. RM9011 kernal functions and procedures. These are called up by the main program.

baud rates are used, which simplifies matters a little. As far as the other factors go, you are on your own.

The module uses no handshaking, so you have to connect various RS232 lines to each other at the computer end, and if necessary tell the operating system which of the handshake lines are in use. It was a great relief when the LED on my RM9011 blinked, signifying that at last I had managed to send it a valid command. The Archimedes serial port is allegedly compatible with the PC-AT (9-pin) type, so the same wiring may work. I have previously used the port with PC-AT compatible peripherals and cables without difficulty. (I will guarantee nothing about any serial port unless I have actually tried it myself. Maybe a bidirectional version of MIDI is the standardisation answer . . .) The RM9011 article carries wiring details for the 25-pin connector, used on older PCs and the type actually specified by the RS232 standard.

```
DEFFNpushbutton(which%)
 LOCAL failed%,i%
 failed%=FNbitwrite(which%,on%)
 FOR i%=0TOpress%:NEXT                  :REM Hold the button for this long
 IF failed% THEN =failed%
 failed%=FNbytewrite(alloff%)
 FOR i%=0TOpress%:NEXT                  :REM Let go for this long
 IF failed% THEN =failed%
=0
REM--------------------------------------------------------------------------
DEFFNstringread(RETURN string$)
REM Values other than zero returned denote errors. See error$() entries.
 LOCAL inbyte%,flags%,limit%,time%,timeout%,terminator%
 string$=""
 timeout%=8       :REM Time limit in centiseconds for reception of reply
 terminator%=13   :REM Reply string must end in this char
 limit%=8         :REM Number of chars received without terminator before we give up
 REPEAT
   time%=TIME
   REPEAT
     IF TIME>(time%+timeout%) THEN =3         :REM Timeout
     SYS"OS_SerialOp",4 TO ,inbyte%;flags%    :REM Get character from serial input buffer
   UNTIL (flags% AND 2)=0
   IF ((inbyte%>31) AND (inbyte%<127)) THEN string$=string$+CHR$(inbyte%)
   IF inbyte%=terminator% THEN =0             :REM Success!
   limit%-=1
 UNTIL limit%<1
=4                                            :REM Terminator not received
REM--------------------------------------------------------------------------
DEFFNconfig(byte%)
=FNserout("C"+STR$(byte% AND 255))
REM--------------------------------------------------------------------------
DEFFNbitwrite(bit%,state%)
  LOCAL outbit%
  IF state%<>0 THEN outbit%=1 ELSE outbit%=0
=FNserout("WB"+CHR$(ASC("0")+(bit%AND7))+CHR$(ASC("0")+outbit%))
REM--------------------------------------------------------------------------
DEFFNbytewrite(byte%)
=FNserout("W"+STR$(byte% AND 255))
REM--------------------------------------------------------------------------
DEFFNserout(command$)
REM Values other than zero returned denote errors. See error$() entries.
 LOCAL i%,flags%,failed%,answer$
 IF command$="" THEN =1        :REM How did this happen, then?
 SYS"OS_SerialOp",3,33         :REM Output "!" to serial port
 IF (flags% AND 2) THEN =2     :REM Serial buffer full
 FOR i%=1 TO LEN(command$)     :REM Output command, one character at a time
   SYS"OS_SerialOp",3,ASC(MID$(command$,i%,1))
   IF (flags% AND 2) THEN =2
 NEXT
 SYS"OS_SerialOp",3,13         :REM Output CR to serial port
 IF (flags% AND 2) THEN =2
 failed%=FNstringread(answer$) :REM Check for RM9011 reply
 IF failed% THEN =failed%
 IF answer$<>reply$ THEN =5    :REM RM9011 unable to carry out write-type command
=0
```

Programming

Programming for this kind of project is always a problem because of the wide variety of computers in use. I don't subscribe to the theory that you all have DOS PCs at home, but you probably do all have access to a reasonably decent version of BASIC. The RM9011 comes with instructions which include sample (and simple) BASIC programs for the PC, to illustrate the use of its commands. It should not be too difficult to modify these to work with almost any computer that has a serial port. The module expects commands composed of ASCII characters, terminated with ASCII 13 (the 'carriage return' character). It replies with another ASCII string, again terminated with an ASCII 13. This command and data protocol can be implemented using the PRINT and INPUT facilities in most BASICs, without needing to handle odd control characters. The RM9011 can accept 7 or 8 bit serial formats at 600 and 1200 baud. Just about all serial ports should be able to manage at least one of the possible combinations.

The supplied BASIC programs are a little, er, basic, and I include here some more sophisticated routines for the Archimedes series of computers. Those of you with other machines should still be able to make use of them, changing the operating system calls ('SYS' statements) and, where necessary, the BASIC syntax. Not all BASICs support LOCAL variables, multi-line IFs or function parameter 'RETURN' directives. All of these features simply add clarity and user-friendliness to the program, and all may be 'worked around' where they do not exist. Variables ending in '%', by the way, denote integers. There should be no difficulty converting to PASCAL or C.

These routines (given in Listing 1) are almost all functions which return an error value, or zero for no error. This technique is mandatory in a multi-tasking environment, and still quite useful elsewhere. It allows errors to be dealt with centrally, as the programmer desires, rather than in the way that the low-level routines are programmed. Those of you with function-less BASICs should set a global variable to the appropriate value and return from the

```
REM Main program and functions for primitive timed record
result%=FNinit
IF result% THEN
  PRINT'"Error!",error$(result%)
  INPUT"Correct problem and press enter"a$
  RUN
ENDIF
REPEAT
  INPUT'"Enter  start time: (dd:dd:dd) "start$
UNTIL FNvalid(start$)
REPEAT
  INPUT'"Enter finish time: (dd:dd:dd) "finish$
UNTIL FNvalid(finish$) AND (finish$ > start$)
PROCtimed_record
PROCtidy
END
REM-----------------------------------------------------------------------
DEFPROCtimed_record
  PRINT'"Standing by to record at "start$
  REPEAT
    a$=RIGHT$(TIME$,8)
    IF (a$ >= start$) AND (finish$ > a$) THEN
      result%=FNrecord
      IF result%<>0 THEN PRINT "Program terminated (2): "error$(result%):END
      state%=record%
    ENDIF
  UNTIL state%=record%
  PRINT'"Recording until "finish$
  REPEAT
    a$=RIGHT$(TIME$,8)
    IF (a$ >= finish$) THEN
      result%=FNstop
      IF result%<>0 THEN PRINT "Program terminated (3): "error$(result%):END
      state%=stop%
    ENDIF
  UNTIL state%=stop%
  PRINT'"Recording completed"
ENDPROC
REM-----------------------------------------------------------------------
DEFFNvalid(test$)
  IF LEN(test$)<>8 THEN =FALSE
  IF (MID$(test$,3,1)<>":") OR (MID$(test$,6,1)<>":") THEN =FALSE
  IF (NOT FNisdigit(MID$(test$,1,1))) OR (NOT FNisdigit(MID$(test$,2,1))) THEN =FALSE
  IF (NOT FNisdigit(MID$(test$,4,1))) OR (NOT FNisdigit(MID$(test$,5,1))) THEN =FALSE
  IF (NOT FNisdigit(MID$(test$,7,1))) OR (NOT FNisdigit(MID$(test$,8,1))) THEN =FALSE
  IF (((ASC(MID$(test$,1,1))-ASC("0"))*10+ASC(MID$(test$,2,1)))-ASC("0"))>23 THEN =FALSE
  IF (((ASC(MID$(test$,4,1))-ASC("0"))*10+ASC(MID$(test$,5,1)))-ASC("0"))>59 THEN =FALSE
  IF (((ASC(MID$(test$,7,1))-ASC("0"))*10+ASC(MID$(test$,8,1)))-ASC("0"))>59 THEN =FALSE
=TRUE
DEFFNisdigit(digit$)
  IF (digit$>"9") OR (digit$<"0") THEN =FALSE
=TRUE
```

Listing 2. Timer-record program. This calls up functions and procedures in Listing 1.

```
REM Main program for testing
result%=FNinit
IF result% THEN
 PRINT'"Error!",error$(result%)
 INPUT"Correct problem and press enter"a$
 RUN
ENDIF
REPEAT
 result%=0
 PRINT"Record/Pause      1"
 PRINT"Record            2"
 PRINT"Play              3"
 PRINT"Pause             4"
 PRINT"Stop              5"
 PRINT"Quit              0"
 INPUT'"Choice? "A%
 IF A%=1 THEN result%=FNrecord_pause
 IF A%=2 THEN result%=FNrecord
 IF A%=3 THEN result%=FNplay
 IF A%=4 THEN result%=FNpause
 IF A%=5 THEN result%=FNstop
UNTIL (A%=0) OR (result%<>0)
IF result%<>0 THEN PRINT "Program terminated (1):
"error$(result%)
PROCtidy
END
```

Listing 3. Main test program. This also calls up functions and procedures in Listing 1.

subroutine. The routines may appear a bit over-engineered, but I learned long-ago to build in lots of hooks and brackets when writing a new program, to which later modifications may be easily attached. And yes, there are *always* later modifications. Extensive use of LOCAL variables, where supported, helps to reduce name clashes and undesirable side effects. I don't claim that the routines are totally bomb-proof, but they will prevent most of my more common programming errors.

One parameter that will vary from one computer (and operating system) to another is the length of time taken to process the reply from the RM9011. There is a timeout value in centiseconds set in FNstringread, which decides how long the program will wait before deciding that there will be no reply. The value stated is adequate for an ARM3 Archimedes multitasking under RISCOS 3, with a baud rate of 1200. No problems will occur if this is set to a very large value, except that debugging will be irritatingly slow. On the other hand, too low a value will completely stop the system working. When you first assemble the system, set it to as high a value as you can stand, and then try reducing it once you have established communication. Final the shortest timeout that works reliably, and then double it to obtain a permanent value. Bear in mind that when you upgrade your computer in a year's time, that if this value is now too low, nothing will work. It will also have to be doubled again if you move from 1200 baud to 600 baud operation.

Along with the routines themselves are two simple main programs: one (Listing 2) is a basic timed record facility and the other (Listing 3) allows direct keyboard control of the recorder's functions. This is useful during the setting up period, when you may not be sure which bit controls which function. Note that the DR-M07 goes into 'record/pause' mode when the 'RECORD' button is pressed, and actually starts recording when the 'PLAY' button is pressed after 'RECORD' has been released. The low-level bit manipulation instructions reflect this. If your deck behaves differently then FNrecord_pause and FNrecord must be modified.

The control program for timed recording can be as elaborate as you like, perhaps duplicating the multi-programme facilities of the typical video recorder. I find a single recording period quite adequate, since the computer and cassette deck will usually be powered via a time-switch, and there is a limit to the sophistication of these devices. I don't really think it wise to leave the equipment turned on for days at a time, and I'm very doubtful about putting a computer in charge of its own on/off switch! Besides, you can't get many radio programmes on even a C120 cassette, unless you have a auto-reverse machine.

It would be possible for Archimedes users to build the routines into one of the many shareware/PD application shells available, to make the system fully multi-tasking. I could not be bothered, as the program produces text output only and will run quite happily in a task window, allowing full use of the computer throughout the recording session. For unattended use, I use the !Alarm application to launch the program as a task after setting two system variables for the on and off times, and then have the program read them on start-up. This is more convenient than building the times into the program, and does not require the program to be started up by the !Boot routine.

So have fun with your serial port. If your cassette deck isn't a Denon DR-M07, or you want to control something entirely different, there will be an element of experimentation involved. You may have to use relays, or even optoisolated triacs, in mains-switching applications. Bear in mind the voltage limitations of the 4000B series ICs, and the lower ratings of the 74HC type, though you are unlikely to find control switches carrying more than 18V. My prototype PCB is used to switch 5V, and a 5V rail is available, so I have not used the 78L05 regulator shown on the circuit diagram.

Inputs as Well

Don't forget, though, that the RM9011 will read bits as well as write to them (not at the same time, but some bits can be set to be read and some to be written to) and can therefore allow some measure of feedback from the controlled device. In my case, the four bits unused for switching could be configured as inputs. Maplin themselves market a wide range of sensor and power control interfaces that can be hooked up to the RM9011 – many of the 'Intelligent Motherboard' peripherals covered in recent issues of *Electronics* will be suitable; in particular the VE92A Open Collector Card (December 1992, Issue 60), VE93B 8-bit Analogue-to-Digital Converter (January 1993, Issue 61), and VF00A Relay Card (February 1993, Issue 62). The RM9011 provides an excellent (and economical) introduction into the world of computer control.

PARTS LIST

RESISTORS: All 1% Metal Film (Unless specified)

R1-R16	47Ω	16	(M47R)
RN1	47k	1	(RA31J)

CAPACITORS

C1,C3	100nF Polyester	2	(BX76H)
C2,C4	22µF 16V Minilect	2	(YY36P)

SEMICONDUCTORS

IC1	ULN2803A	1	(QY79L)
IC2,IC3	HCF4066BEY	2	(QX23A)
RG1	LM78L05ACZ	1	(QL26D)

MISCELLANEOUS

L1	100µH RF Choke	1	(WH41U)
	14-Pin DIL Socket	2	(BL18U)
	18-Pin DIL Socket	1	(HQ76H)
	PCB Pin 2141	1 Pkt	(FL21X)
	RM9011 Interface Module	1	(LP85G)
	Constructors' Guide	1	(XH79L)
	PCB, connectors, ribbon cable, mounting hardware – all as per user requirement		

The Maplin 'Get-You-Working' Service is not available for this project.

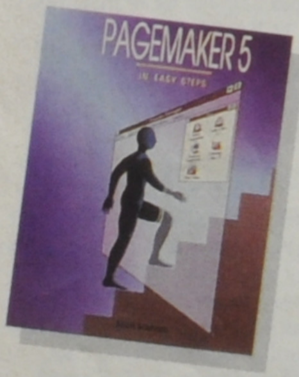
The above items are not available as a kit.

NEW BOOKS

Pagemaker 5 – In Easy Steps

by Scott Basham

DTP systems based on PCs are now being used to create virtually any kind of document previously associated with traditional publishing. Pagemaker 5 has many helpful facilities to import text and artwork from other computer applications packages, as well as the ability to generate directly from within the software itself.



This enjoyable guide covers all the essential features of Pagemaker 5 for Windows and includes; drawing and manipulating shapes; importing text and graphics; cropping, skewing, reflecting and rotating objects; story and table editing; kerning and tracking; producing contents table and index pages; working with colour and printing; how to create and work with a publication, and useful tips and techniques for good document design.

This book is designed to be just like Pagemaker 5 – graphical, and is a clear, concise guide that is intended to teach all the essentials of the software in easy steps. The book has been specifically written for version 5 and is not a revamped book about earlier versions. All screen shots and other material used refers directly to the UK/international English version of the product.

The guide is packed with useful tips and can be used as a self-teaching tutorial or as an easy reference guide. Also, Apple Mac users will find the book extremely useful, since the software is virtually identical on both machines
1993. 125 pages. 227 x 186mm, illustrated.

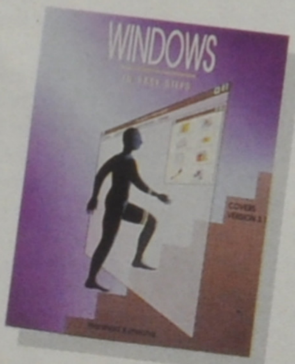
Order As AA17T (Pagemaker 5) £14.95 NV

Windows – In Easy Steps

by Harshad Kotecha

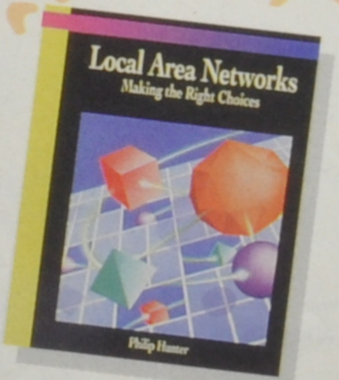
The advent of 'Windows' for the PC has certainly made using a PC much more user-friendly. Software designed to run under Windows has the same consistent 'look and feel', so once you have mastered one Windows package, it is much easier to learn another. One of the many features of Windows is 'multitasking' which, when used on a suitably equipped PC, allows several programs to be available simultaneously. This facility allows you to print a large document from your wordprocessor and whilst this task is going on, open another application, such as a spreadsheet.

Another very powerful feature is 'object linking and embedding' (OLE) which allows you to share information between applications by linking them into new documents you create. A graphic created in one drawing software package can be linked or embedded into a wordprocessor document.



This graphically illustrated guide takes you through these and many more techniques in a clear and concise way. Topics covered include; automating start ups; copying and moving files, and directories; customising Windows; using screen savers, Write and Paintbrush; organising the desktop, and many more. This invaluable book can be used as an easy reference guide or as a self-teaching tutorial. It is filled with useful tips, notes and shortcuts, making it invaluable for all Windows users.
1992. 128 pages. 227 x 186mm, illustrated.

Order As AA16S (Windows In Easy Step) £9.95 NV



Local Area Networks – Making the Right Choices

by Philip Hunter

Local area networks (LAN) are now an indispensable part of computer installations in small and medium size businesses being the only practical way to share applications and resources such as printers. Without a LAN, it is extremely difficult for companies to exploit information technology (IT) efficiently or competitively.

For those who are about to install a LAN, or to upgrade or expand an existing one, then this book will help you choose a LAN system that is compatible with your business requirements and objectives. The book has been written in a non-technical style and is intended to help you to select the most suitable LAN components for your particular requirements or installations. Additionally, the book discusses the skills needed to manage a LAN effectively – a factor that needs to be considered in estimating the cost of a LAN network.

The book will help you make decisions such as components required and choice of supplier, whether to opt for Ethernet or Token ring, whether you should have a structured cabling system, and a network operating system. All these topics and many more are covered in this detailed and informative book. The final chapter includes a case study that is intended to draw together all the issues covered to provide an overall perspective of a LAN installation. For many years, the author has been an information technology journalist specialising in networking and telecommunications.
1993. 340 pages. 233 x 173mm, illustrated.

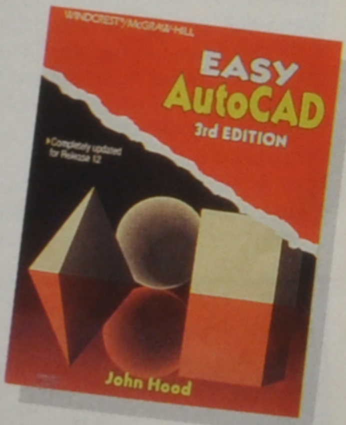
Order As AA19V (Local Area Networks) £17.95 NV

Easy AutoCad – 3rd Edition

by John Hood

AutoCad is a computer-aided drafting CAD program that is primarily intended to run on 80386/486 PCs, and has become the industry standard microcomputer CAD program.

The third edition of this informative text book now covers AutoCad Releases 11, 12 and Windows for AutoCad. This edition, as before, has been written in a way that immediately involves the student in the drawing process. This edition now includes the use of pull-down menus and dialogue boxes along with the standard screen menu. The text is composed of a series of tutorial projects each about three hours in length which are designed to bring the novice user, with no experience, to the level of a fully-trained CAD operator in a short period of time. The student should be able to master all the powerful features of AutoCad such as dimensioning, layering, isometric drawing, 3-D drawing, attributes, solid 3-D modelling, multiview drawings, blocks and much more.



Primarily, the text is intended to supplement the AutoCad Reference Manual, by teaching the reader how to produce industrial drawings. Each chapter builds on the knowledge gained from previous chapters, so that efficient drawing techniques are acquired in a progressive manner.
1993. 386 pages. 233 x 188, illustrated. American Book.

Order As AA18U (Easy AutoCad) £19.95 NV

These descriptions are necessarily short. Ensure that you know exactly what the kit is and what it comprises before ordering, by checking the issue of *Electronics* referred to in the list.

The referenced back-numbers of *Electronics* can be obtained, subject to availability, at £1.95 per copy.

Carriage Codes – Add; A: £1.45, B: £2.10, C: £2.65, D: £3.15, E: £3.70, F: £4.25, G: £5.10, H: £5.70.

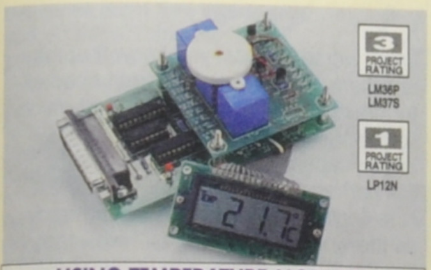
DID YOU MISS THESE PROJECTS?

The Maplin "Get-You-Working" Service is available on ALL of these projects.

To order Project Kits or Back-numbers of Electronics, 'phone Credit Card Sales on (0702) 554161. Alternatively, send off the Order Form in this issue, or visit your local Maplin Store. See base of this page for locations of Maplin stores.

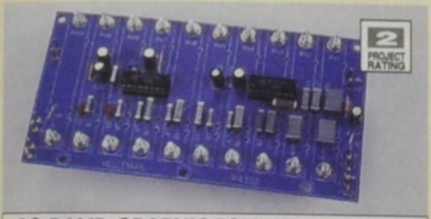
Maplin: The Positive Force In Electronics

All items subject to availability. Prices include VAT.



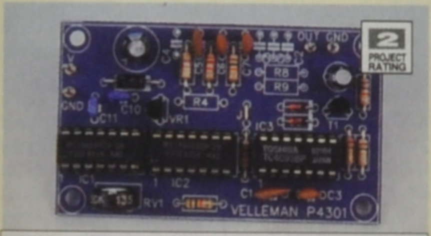
USING TEMPERATURE MODULES

This very practical *Electronics* article details the use of the following projects which, when used in conjunction with the range of temperature modules available from Maplin, can provide some extremely versatile environmental control functions.
Order as: LM37S (Relay Interface Card Kit), **Price £12.45**; LM36P (Serial/Parallel Converter Kit), **Price £14.95**; LP12N (24-line PC I/O Card), **Price £21.95**. Details in *Electronics* No. 71 (XA71N).



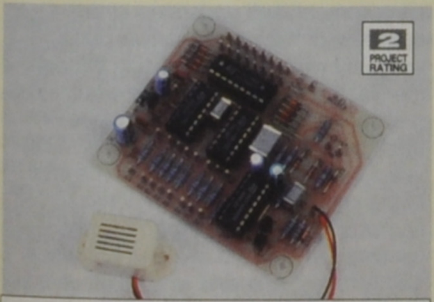
10-BAND GRAPHIC EQUALISER MODULE

This easy to build equaliser project has ten frequency bands that allow you to adjust audio response to your particular preference.
Order as: VE44X, **Price £34.95**. Details in *Electronics* No. 71 (XA71N).



PINK NOISE GENERATOR

This easy to build pink noise generator employs a pseudo-random digital noise source and can be easily adapted to produce white noise if required.
Order as: VE43W, **Price £11.95**. Details in *Electronics* No. 72 (XA72P).

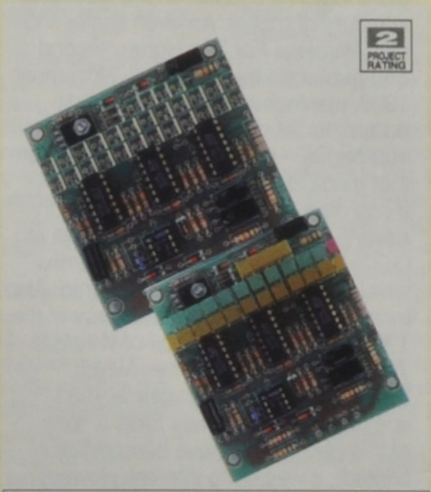


PRIORITY QUIZ BUZZER

No more arguments about who got the answer first! This versatile system allows up to eight contestants to battle it out without altercation, and can be expanded in blocks of eight by simply adding more units. Order as: LT41U,
Price £9.95. Details in *Electronics* No. 72 (XA72P).

DIGITAL MODEL TRAIN CONTROLLER

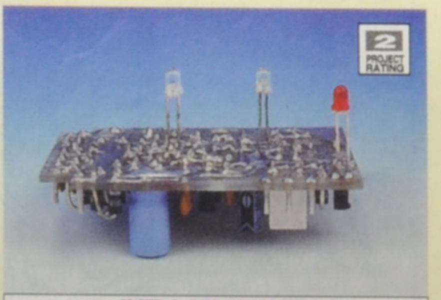
This versatile project allows you to control up to fourteen locomotives on a single layout, with up to four locomotives being active at any one time. The basis of the system is a Common/PSU board, to which one controller is added for each *active* locomotive. All locomotives require a receiver. To complete the project, a smart, pre-drilled case is available.
Order as: LW61R (Common/PSU), **Price £39.95** C4; LW62S (Controller), **Price £9.95**; LT29G (Receiver), **Price £12.95**; XG09K (Case), **Price £24.95**. Details in *Electronics* No. 71 (XA71N).



LED POWER METER

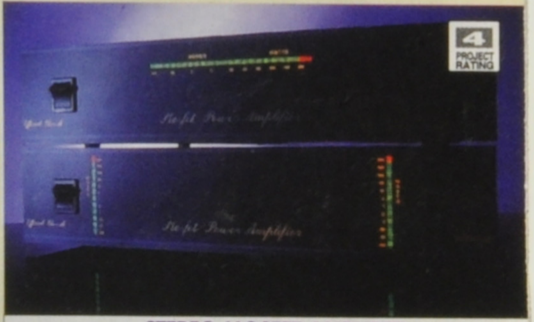
A pair of LED power meters for the Velleman Stereo MOSFET Amplifier, VF17T. The meters can be used in either stereo or mono configuration. Order as: VF18U, **Price £34.95**. Details in *Electronics* No. 72 (XA72P).

Visit our stores in: Birmingham, Brighton, Bristol, Cardiff, Chatham, Coventry, **Edinburgh, Glasgow**, Ilford, Leeds, Leicester, London (Edgware, Forest Hill and Hammersmith), Manchester (Oxford Road and Cheetham Hill), Middlesbrough, Newcastle-upon-Tyne (The Metro Centre, Gateshead), Nottingham, Portsmouth, Reading, Sheffield, Slough, Southampton, Southend-on-Sea, Stockport, plus NEW stores opening soon in Northampton and Milton Keynes. Ring 0702 552911 for further details.



INFRA-RED SWITCH

Look, no hands! This versatile remote control switch can operate a multitude of electrical or electronic equipment without you even touching it.
Order as: LT38R, **Price £9.95**. Details in *Electronics* No. 71 (XA71N).



STEREO MOSFET AMPLIFIER

A superb high power stereo amplifier that sounds as good as it looks. Bridged configuration transforms the unit into a 600W (music power) mono amplifier.
Order as: VF17T, **Price £299.95** H29. Details in *Electronics* No. 71 (XA71N).

TWINKLING CHRISTMAS CANDLE

This simple to build, high tech electronic candle has a realistic pseudo-random flicker, but won't burn a hole in your pocket–or anything else for that matter. Ideal for decorations or plays, as there is no danger of fire, or of the flame being blown out. The kit includes constructional details of a suitable cardboard lantern for the festive season. Order as: LT40T, **Price £6.95**. Details in *Electronics* No. 72 (XA72P).

Stray Signals

by Point Contact

This year PC and the XYL stayed with friends in York again for a few days. We re-explored the surrounding countryside, visiting again the famous abbeys of Riveaux, Fountains and Bolton, as well as visiting various places where we had not been before, such as Whitby. Another place which was new to us was the famed-in-song hill town of Richmond, with its castle which we duly visited. Then, whilst Mrs. PC went into a shop in the main square to buy a hunk of cheese to go with our al fresco lunch, PC descended into the basement of the building, which housed a second-hand bookshop. Having an interest in old books about electronics, which in pre-war days was synonymous with 'wireless', I never pass by a second-hand bookshop, always hoping to find a rare work on the subject. PC enquired of the proprietor, more in hope than expectation, if he had any pre-war books relating to wireless. Many such establishments just don't know whether they have or not and in some cases the books are hardly sorted by subject at all. PC was pleasantly surprised to be directed by the cheerful and efficient proprietor to a cardboard box on the floor in the far room, halfway along on the left-hand side. Sure enough, there was the box, clearly labelled 'WIRELESS – RADIO – TV', and on pulling it out from under the bottom shelf it proved to contain several books of interest, three of which I bought. One was a rather dog-eared copy of *'AP1762'*, issued October 1939. This 'Air Publication' is entitled *Electrical and Radio Notes For Wireless Operators*, published by His Majesty's Stationery Office, in soft covers, at three shillings and sixpence net. This Air Ministry publication is nothing other than a complete, if simplified, course in 16 chapters covering electricity and radio, starting with a chapter on the electronic structure of matter. An even earlier find was *Wireless For The Home* (second ed.) published by Pitman's in November 1922, just four months after the first edition. Its 23 chapters occupy less than 100 pages – presumably there was not that much to say about the subject in those days. The book contains sundry adverts by various companies, such as GEC, Mullard and for the rest, names which have long since disappeared. Also in the box was the inevitable copy of the 1938 *Admiralty Handbook of Wireless Telegraphy* in two volumes (which superseded the single volume 1931 edition), but as I already have a copy of this (there must have been millions printed), it was of no interest. However, I *did* buy a copy, of the 1925 edition, printed in 1928, that was in a very fair condition. The foreword states that it supersedes the 1920 edition, so does anyone know if that was the *first* edition? Anyway, I shall certainly keep an eye out for it.

ZEV development is all the rage nowadays for zero emission vehicles would be such a boon to the poor pedestrian fighting his way through a fog of petrol and diesel fumes in any town or city centre. The fumes from petrol-driven vehicles are no less poisonous than diesel fumes, but although the latter smell worse, at least you know that they are there. But the breakthrough needed for practicable ZEVs in the form of much lighter secondary batteries with much higher capacity and energy density is still perhaps decades away. So interest is rekindling in LEVs, once stigmatised as the worst of both worlds – why carry around a heat engine and generator as extra payload when running on batteries? – so the argument went. But if the motor-generator can be made light enough, the scheme begins to make sense. Due to limited range, current ZEVs are really only round-town runabouts, a normal car being needed for those longer journeys. But with the battery/electric-motor combo to look after normal motoring and particularly the power-hungry acceleration requirements, the motor-generator set (only used on long journeys) can run at constant design full load, where efficiency is maximum. Better, the argument runs, to reduce air pollution now by around 70% than wait for a 95% reduction which may be possibly decades away, especially as the former does not rule out the latter anyway. Volvo have recently announced a four-door family car having a 56kW (70kW peak) traction motor and a 16·8kWh Ni-Cd battery good for about 50 miles of round town driving. An integrated gas-turbine/generator unit delivers 39kW for battery charging on long journeys. I guess the only thing stopping it taking off like sliced bread is the initial cost, which the news item did not mention.

Talking of storage batteries reminds me of the 2V accumulator which powered the filaments of the battery valves in the home-made wireless set which was still in use at my grandparents long after the war. In the side of the square glass outer container was a pointer that was hinged at one end. The other end moved up or down over an arc scaled from 'empty' at the bottom to 'full' at the top. As a lad at the time, I was in the old-clocks-and-Meccano phase of development, and understood the operation of things mechanical quite well. So I was always squinting through the glass, trying in vain to see what mechanism made the pointer move – there appeared to be nothing at all. Only years later did I realise that the material of the pointer had the same density as the acid in a half charged battery, causing it to point up at about 45° when fully charged, and sink when exhausted.

Yours sincerely

Point Contact

The opinions expressed by the author are not necessarily those of the publisher or the editor.

A readers forum for your views and comments.
If you want to contribute, write to:

The Editor, 'Electronics – The Maplin Magazine'
P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Dear Editor

AIR YOUR VIEWS

Green Transistors

Dear Editor,
I was fascinated to see the reference, in the item on page 14 of the December 1993 issue of *Electronics* about John Woodgate's work on a Pye 'Transhailer', to 'geranium' transistors. Presumably, since these are basically 'green', they are more environmentally friendly than their modern silicon based equivalents?
Alan Cox, St. Clears, Dyfed.

Dear Sir,
I thought that 'flower power' went out in the 60s. I am of course referring to Mr. Woodgate's News Report item in Issue 72. Thanks for the chuckle anyway.
Don Bray, Seaford, Sussex.

Oops! We certainly slipped-up there! Apologies are due to John Woodgate, who, in the same news story, we referred to as principle of JMWA; he is of course the Principal. I have passed a germanium transistor and a geranium to our News Editor, Stephen Waddington, so he knows the difference in future! Oh, well at least it made you all smile!

Beware of the Leaky Caps

Dear Maplin,
How wonderful to see all the valve articles appearing. It takes me back to when I was a teenager, building valve guitar and PA amplifiers. Not being much of a mathematician, all my circuits were devised from 'building blocks' lifted from textbooks and magazines, with me putting them together, wondering why they didn't work, then fiddling and tweaking and playing around until the circuit worked satisfactorily. There were many hours of frustration, moments of extreme danger – like when an electrolytic exploded having 500V applied to it in reverse polarity by mistake – and moments of great joy, for example when my 100W, class AB1 ultra-linear design proved to be extremely effective in tandem with my Fender lookalike guitar.
Basically I am writing in support of Mr. Rod Hall's letter published in the December issue, requesting the design of a guitar amp. I was impressed to read about the noise figures for your 4-20 amp. Perhaps you could come up with something similar for the guitar aficionados?
In addition to previous discussions about which type of phase splitter to use, I will also add that the use of top quality, 1000V capacitors are essential, especially into the output stage. My designs regularly suffered from leaky coupling caps in the 60s.
Dallas Simpson, Nottingham.

Yes, leaky coupling caps were a common fault in many a valve amp, even commercial ones after a few years, when the capacitors deteriorated. Apart from funny noises, one other clue that all is not as it should be is a glowing, cherry-red anode in an output valve! This is a direct result of the valve being forward biased *by the leakage current through the capacitor. Such coupling capacitors should not only have a high voltage rating, but also have a very high insulation resistance across the dielectric. Modern ones which fit the bill are polypropylene types. Electrolytics* must never *be used for coupling in driver/output stages!*

★★★★★★★★★★★★★★★★★★★★

S·T·A·R L·E·T·T·E·R

This month's Star Letter Award winner of a £5 Maplin Gift Token is Mr. C. Dupont from Poole in Dorset, for his suggestion about making professional-looking front panels.

★★★★★★★★★★★★★★★★★★★★

Up Front

Dear Sir,
The main thing that distinguishes a completed 'professional looking' project from a home-made bit of kit are the legends and such which support the functionality of the various controls, etc.
For the layman, these are impossible to produce to a professional standard. However, you can supply the key, as was sometimes done in the past (e.g., Signal Generator some time ago), by printing appropriate front panel legends accompanying the project article in your mag, to scale and to suit the suggested mounting box, etc.
These can then be photocopied and stuck to the housing. Very acceptable results are obtained, and what a difference it makes compared to using stencils, or the 'naff' look that dymo tape so often gives to projects.
Sometimes you do supply a front panel for projects, for example Tetraprobe, as an optional item – but what a cost they tend to be!

We have printed same-size front panel labels in the past and we will continue to do so in the future, but more often!
Here are a few useful tips to help you. When photocopying a panel design, if any printing from the reverse side of the page shows through, place a sheet of black paper behind the page to be copied. To prevent the photocopy becoming wrinkled, use a spray-on adhesive such as 3M Spray Mount or 3M Display Mount (available from art shops). Clear adhesive film such as Fablon (available from Woolworths and hardware stores) can be applied to prevent the panel being marked or damaged by everyday use. We are also making more use of pre-printed stick-on front panel labels, these are a lot cheaper than the pre-drilled and printed panels that we have used in the past. Even when a pre-printed label is available, we will still print the design so you can choose which method you want to use.

★★★★★★★★★★★★★★★★★★★★

On a Charge

Dear Sir,
I was intrigued by the letter from J. K. Richards of Chelmsford in Issue 70 concerning his problems with charging a caravan battery. He mentions a 'split charge circuit on the tow vehicle', and I am very curious as to what this might be.
Caravanning is very popular here in North America, where we call them 'trailers' or 'campers', and they invariably have at least one 12V battery. We use one of two methods to charge them from the tow vehicle's alternator. I have used both with equal satisfaction. The primary concern is that the battery in the tow vehicle is not discharged by the caravan. One method is the 'battery isolator' which is a pair of 80A diodes with anodes commoned at the alternator output and each cathode going to each battery. The other method is to connect the two batteries together only when the engine is running with a relay.
Michael Stonebridge, Alberta, Canada.

The split charge circuit, which you enquire about, is commonly just a relay that connects the battery in the trailer to the alternator, when the ignition is switched on or, preferably, when the alternator is producing sufficient output to charge both of the batteries. A further variation is where two relays are used, the first is used to charge the trailer battery, as previously mentioned, the second is used to supply power to the caravan's gas/mains/12V 'fridge. The idea being that by the time you reach the camp-site, the 'fridge is already down to working temperature, can be switched over to gas operation and used immediately. However, most split charge units do not provide any indication whatsoever of 'charging' or 'fault' conditions, this would prevent the flat battery problems experienced by Mr. Richards.

Cat Calls

Dear Editor,
In your editorial for the November '93 issue, you ask for comments on the 1994 catalogue. Whilst the colour is useful and the various tips are interesting, I find the new section sequence abysmal. I am forever having to look in the index as I have not yet determined any logic in the arrangement. Please revert to the well established sequence for your next issue.
John Huddleston, Abingdon, Oxon.

Dear Sir,
You invited comments about the new Colour Maplin Catalogue, well I think it's brilliant, and I don't just mean the colour pictures; the range of products is better than ever! Keep up the good work, and keep the catalogue colour next year too.
P. Driscoll, Sussex.

The restructuring of the catalogue sections has attracted quite a few comments. All we can say at the moment is that your comments have been noted and passed to the relevant department. Please keep your comments coming.

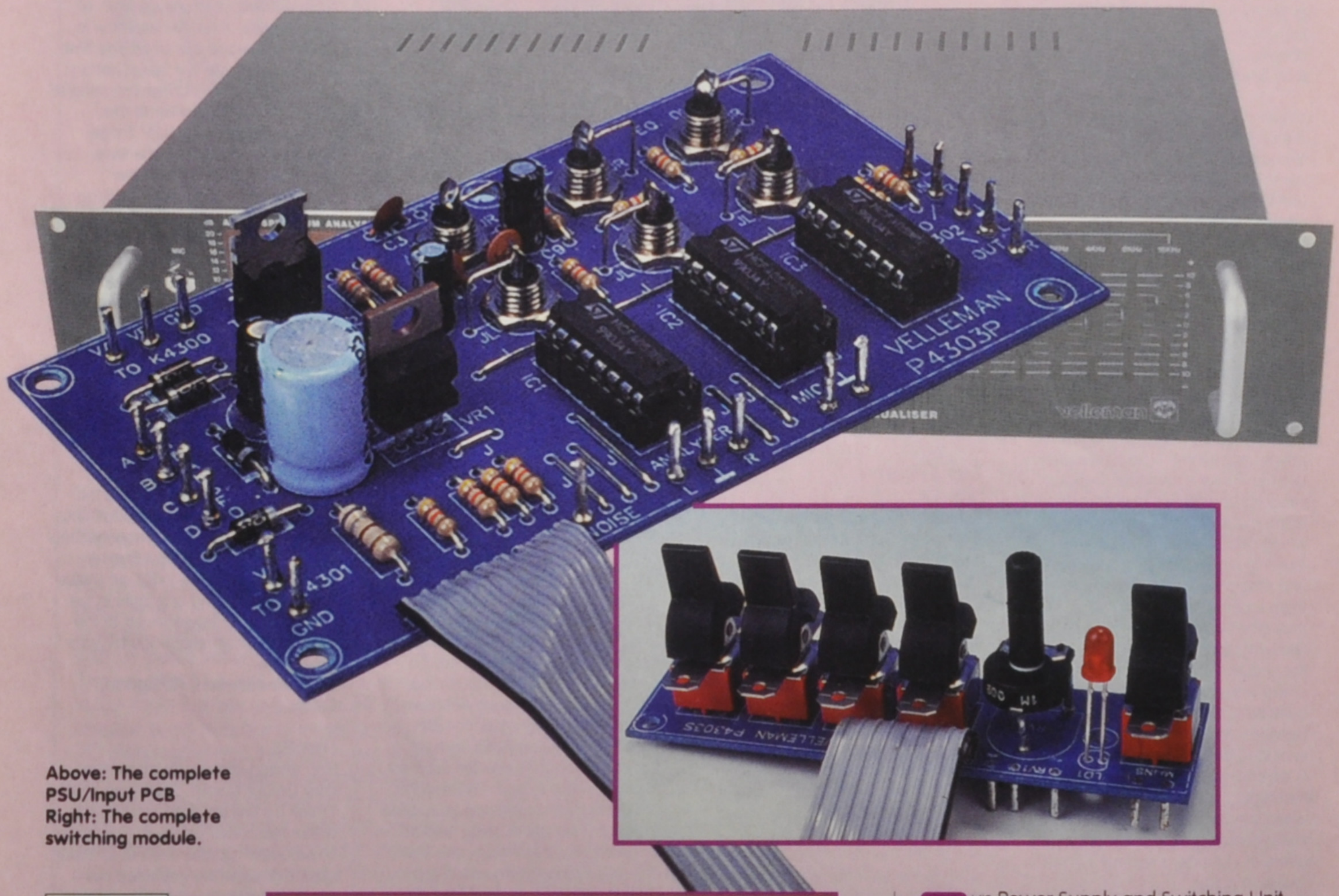
Oops!

A special message to one of our readers, Mr. Mark Elder of London, whose letter, published in Issue 72, requested info on the Dynaco A470 valve amplifier. We now have this and some other data which we could pass on to you, if it wasn't for one small problem – we seem to have lost your address! (Probably got filed under 'B' for 'bin' by mistake.) If you post your details to the usual address (above) we can get the envelope off to you as soon as possible.

KIT AVAILABLE (VE45Y)
Price £32.95

Graphic Equaliser Power Supply & Switching Unit

Text by Alan Williamson and Mike Holmes



Above: The complete PSU/Input PCB
Right: The complete switching module.

3
PROJECT RATING

FEATURES

- **Input from Line or Noise Generator**
- **Tape Output from Line or Equaliser**
- **Spectrum Analyser Input from Line or Microphone**
- **Line Output from Line Input or Equaliser**

This Power Supply and Switching Unit module has been designed for use with the Modular Graphic Equaliser System, which is made up from the other modules which were, *or will be in the case of the Front Panel*, featured in other issues of *Electronics*. These are:

K4300 (VE42V)	Audio Spectrum Analyser (Issue 70)
K4302 (VE44X)	10-Band Graphic Equaliser (Issue 71)
K4301 (VE43W)	Pink Noise Generator (Issue 72)
F4302 (VE41U)	Front Panel (Issue 74 *(to follow)*

This kit has been designed to perform three functions. These are: 1. provide a regulated power supply for the above modules; 2. provide all the necessary switching functions; and 3. include a front panel mounted line input sensitivity control.

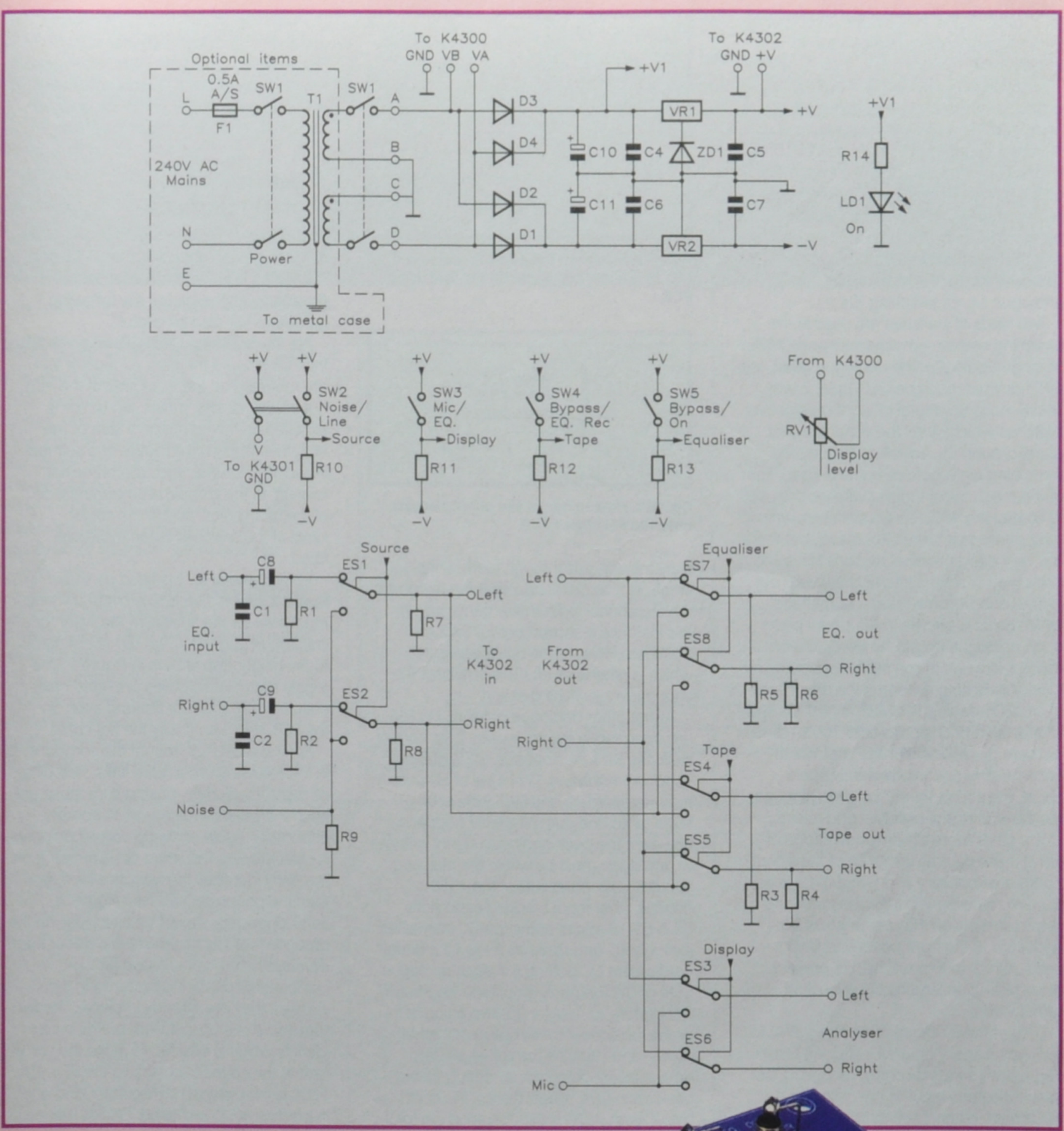
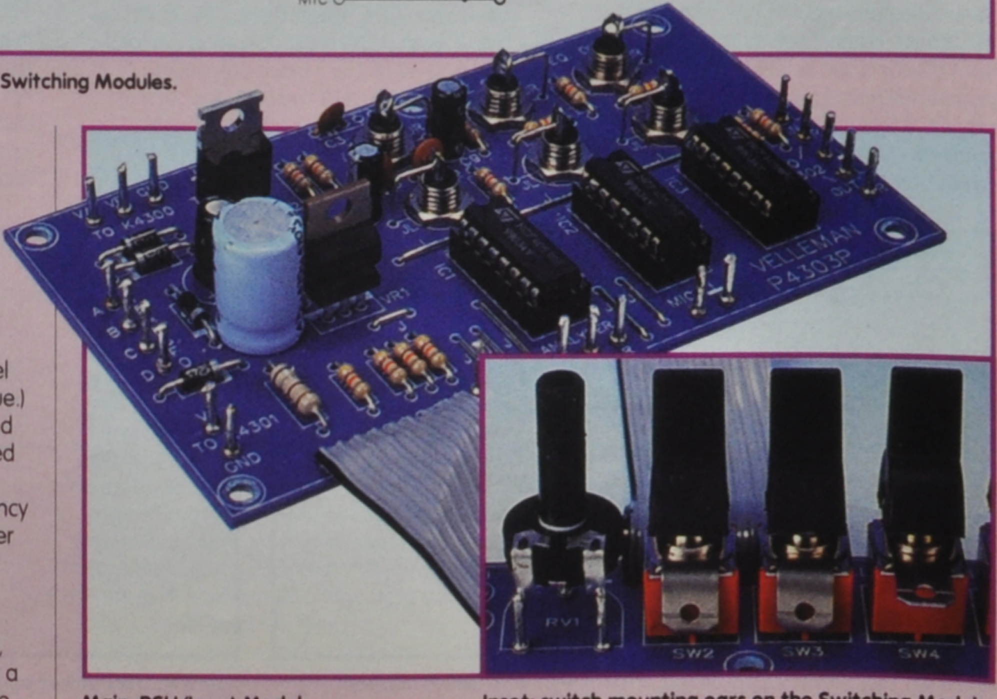


Figure 1. Circuit diagram of PSU/Input and Switching Modules.

Circuit Description

Figure 1 shows circuit diagrams of the power supply, function control switches and the signal switching block. In the power supply section, Diodes D1 to D4 form a bridge rectifier for the incoming 12-0-12V AC source. (Items shown within the dashed area 'Optional items' will be discussed in more detail in the Front Panel and final assembly details in the next issue.) Smoothing and decoupling of the plus and minus DC supply voltage rails are provided by C10 & C4, C11 & C6. C4 & C6 are included to help remove any high-frequency noise from the rails, as these have a better high-frequency performance than the electrolytics.

Regulation of the positive supply is performed by the 7808 regulator IC (VR1), which is capable of supplying up to 1A at a stabilised 8V output. The 2·4V Zener diode



Main: PSU/Input Module.

Inset: switch mounting ears on the Switching Module.

(ZD1) is added to 'jack up' the 8V output of the voltage regulator to the required 10V level (actually 10·4V).

Regulation of the negative supply is achieved with a 7905 voltage regulator (VR2), providing –5V output again to a maximum current of 1A. Capacitors C5 & C7 decouple the output of the regulators and a power 'ON' status indicator is provided by LED LD1. The total supply potential is, then, 15V with 0V or ground potential fixed between these two levels. This arrangement is required by the analogue signal switching ICs.

Two kinds of switches are used in the switching section – mechanical and CMOS analogue gate ICs. The analogue gates are 4053 devices, each being 3-pole, 2-way. These make up a total of eight changeover switches which direct the various signal paths around the equaliser system; the remaining ninth gate remains unused. Four of the mechanical toggle switches are used to control the 4053 CMOS switches, which may seem a bit 'Heath Robinson', but there are very good practical reasons for doing it this way. Mechanical switches wear out in time and become noisy – something which is not desirable in the signal paths of an analogue circuit! However, a worn mechanical switch can still be adequate for control switching, whereas the advantage of a CMOS analogue switch is that it is silent in operation and is practically 100% reliable, as there are no mechanical contacts to become dirty and intermittently open circuit, the sort of thing that often plagues mechanical signal switches and relays.

The other more obvious advantage of using these devices is that all of the signal tracks are kept very short, and there is no need to route signals from the input and output sockets on the rear panel of the enclosure to the front panel and back again, which in turn will help to prevent noise pick-up in lengths of connecting signal leads.

Each of the four control switches SW2 to SW5 has a specific signal switching function, and merely sends a control voltage to the relevant control input of the associated 4053 gate. When, for example, SW2 (Input from Line or Noise selector) is closed, a positive voltage signal at supply level is sent via the control line to analogue switches ES1 & ES2, causing the gates which normally connect the left and right stereo line inputs through to the equaliser stage, etc., to close, and opening the gates which connect to the noise generator. (In this instance a second part of SW2 also switches power to the noise generator, which is otherwise off.) This emulates the changeover switching action.

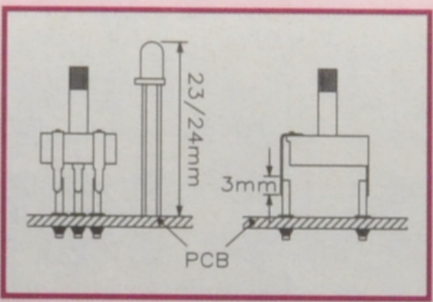


Figure 2. Mounting the potentiometer and LED to the correct height on the Switching PCB.

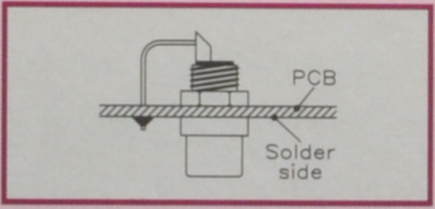


Figure 3. How to mount the phono sockets onto the PSU/Input PCB.

All the other analogue gates ES3 to ES8 are operated in the same way from control switches SW3 (Microphone or EQ output to Spectrum Analyser), SW4 (Line or EQ output to tape recorder), and SW5 (Line in or EQ to main Line out). Whatever happens, however, the peak analogue signal voltage at any stage must be within the plus and minus supply potentials of the 4053 devices. After input blocking capacitors C8 & C9, all signal paths are DC connected throughout, and resistors R1 to R8 maintain a quiescent DC potential in each analogue gate of 0V. The peak amplitude 'headroom' is therefore <+10V for positive going half-cycles, and >–5V for negative going half-cycles, and explains the rather curious arrangement of the power supply. Being basically a CMOS logic device, the control line of each 4053 must also span the total supply level of 15V. Hence pull-down resistors R10 to R13 maintain the control lines at minus supply potential where any of the switches SW2 to SW5 are off. And that, basically, is all there is to it.

The third part of the circuit is a front panel mounted potentiometer to control the sensitivity of the line input; please note however, that if used, the potentiometer (RV1) mounted on the spectrum analyser line amplifier PCB must **not** be fitted.

Additional Construction

There are two PCBs to build. These consist of the main analogue switching PCB and the control PCB. A construction leaflet is provided with the kit, but the following guidelines will also be useful.

For the Switching Unit PCB, begin by fitting the PCB pins. All the pins, *except* for RV1, are mounted on the *track* side of the PCB. Cut off any excess 'mains' pin which is exposed on the component side of the PCB, then apply a thick layer of a suitable insulating material, such as conformal coating, to the cropped component side of the mains pins, and to the solder joints of the switches when these are fitted.

Potentiometer RV1 is fitted as shown in Figure 2. Its function is to provide a variable input level for the Spectrum Analyser for calibration purposes. The LED is also fitted to the height also shown in Figure 2. The toggle switch assemblies are fitted next, ensuring that they are flat and even on the PCB, and then finally the flat cable.

For the main PCB, mount the components in the following order: wire links, PCB pins, all resistors, diodes, making sure these are fitted the correct way round; IC sockets, capacitors, again ensuring correct polarity – for electrolytics, the stripe or (–) marking on the body identifies the *negative* lead; and then the phono sockets (see Figure 3). Semiconductors should be fitted last, on the grounds that this minimises the risk of heat damage (which is increased if other components are being soldered in the vicinity if they are already in place). The two regulators can be installed, but be sure to identify which is which and place the correct type in the correct location on the PCB. The 7808 is the positive rail regulator and goes in position 'VR1', while the 7905 is the negative rail regulator for position 'VR2'. Finally the ICs can be inserted into their sockets; *be sure* to align the pin 1 marker on the package of each with the pin 1 identifier on the legend.

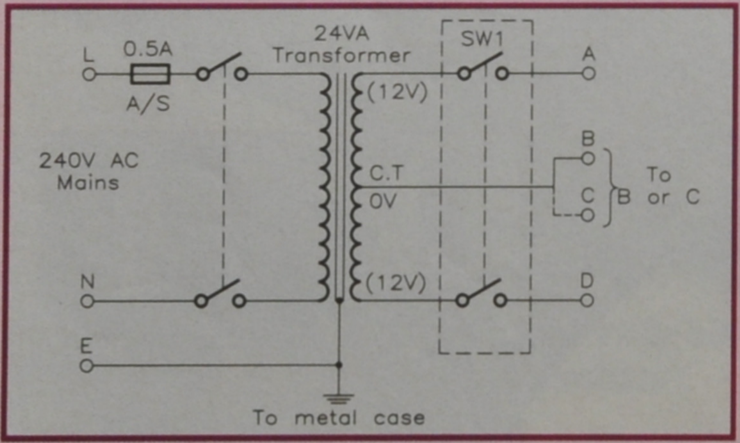


Figure 4a. Test power supply option: transformer with centre-tapped secondary

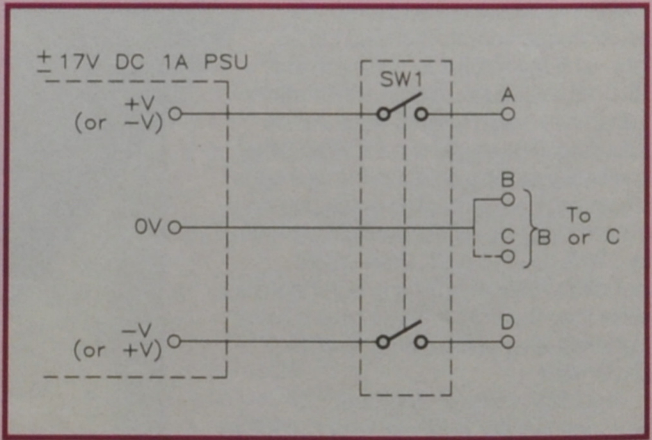


Figure 4b. Test power supply option: using a dual rail ±17V DC power supply.

SW2	Source	Noise Line	Up Down	ES1 & ES2	Noise output to Equaliser (K4302) input EQ. (Line) input to Equaliser (K4302) input
SW3	Display	Mic EQ.	Up Down	ES3 & ES6	Mic. input to Spectrum Analyser (K4300) input Equaliser (K4302) output to Spectrum Analyser (K4300) input
SW4	Tape	Bypass EQ. Rec.	Up Down	ES4 & ES5	EQ. (Line)/Noise input to Tape out via ES1 & ES2 Equaliser (K4302) output to Tape out
SW5	Equaliser	Bypass On	Up Down	ES7 & ES8	EQ. (Line)/Noise input to EQ. out Equaliser (K4302) output to EQ. out

SW1 is for switching the transformer secondary output to the unit.

Table 1. Detail of the analogue switch controls.

Testing and Setting Up

To be able to test the module on its own a ±15V symmetrical supply (AC or DC) is required, and a multimeter. The symmetrical supply can be a transformer with dual 12V secondaries, as that in Figure 1, or one with a centre tapped 12-0-12V secondary as shown in Figure 4a, or dual rail DC power supply with plus and minus 17V DC outputs either side of a common 0V, as in Figure 4b.

Temporarily connect and solder shorting links across both capacitors C8 & C9. Connect the test PSU plus and minus supply rails to the pins 'A' & 'D', and the PSU 0V to 'B' or 'C'. Ensure that all switches SW2 to SW5 are in the 'up' or 'off' position, then switch on the PSU. The LED should illuminate. Set the multimeter to the appropriate range to read 200Ω, and connect the meter to the appropriate points of the circuit to check continuity through each of the CMOS analogue switches; a reading of approximately 120 to 130Ω should be obtained for each switch in the closed (on) position, infinity for the open (off) position. Select the highest resistance range on the ohmeter to check for leakage in the open state.

Table 1 shows which mechanical switch operates which CMOS switches and their connections.

Once all the CMOS switches have been checked out and found to be functioning correctly, the power supply can be switched off and disconnected, and the shorting links fitted across capacitors C8 & C9 can then be removed.

Figure 5a shows drilling details for the six phono sockets on the rear panel of the case, while Figure 5b shows drilling details for the switch assembly on the front panel.

Next month sees the final part of the series, which covers the assembly of all the modules into an enclosure, the front panel, interconnect and mains wiring.

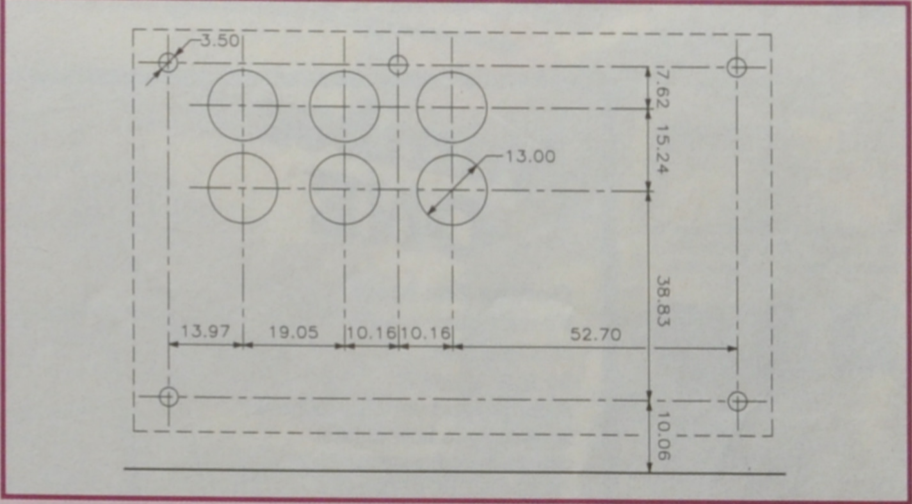


Figure 5a. Drilling details for the input/output phono sockets on the rear panel; PCB dimensions shown dotted.

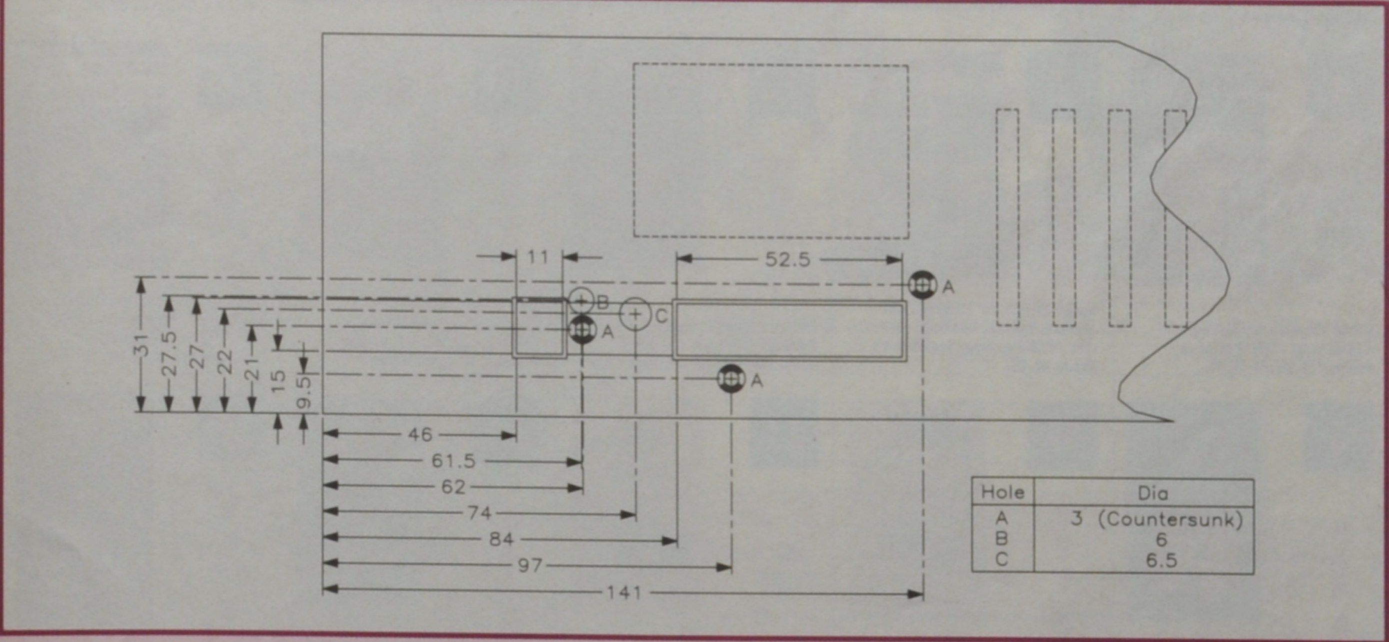


Figure 5b. Front panel drilling for the switch assembly. Rectangular hole at left is for SW1, at right for SW2 to SW5. Hole C is for the front panel potentiometer.

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

This project is available in kit form only.

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Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

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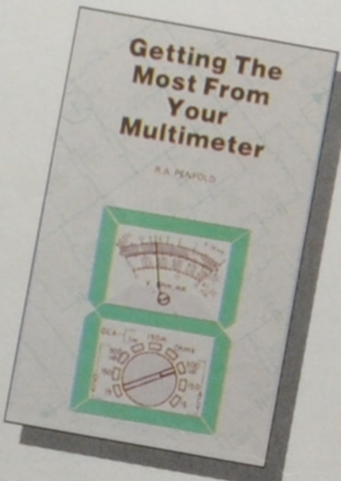

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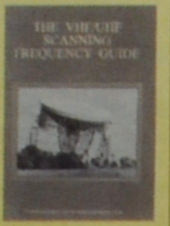

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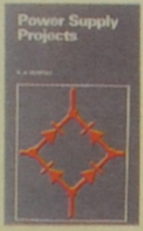

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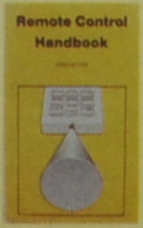

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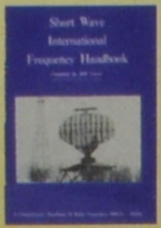

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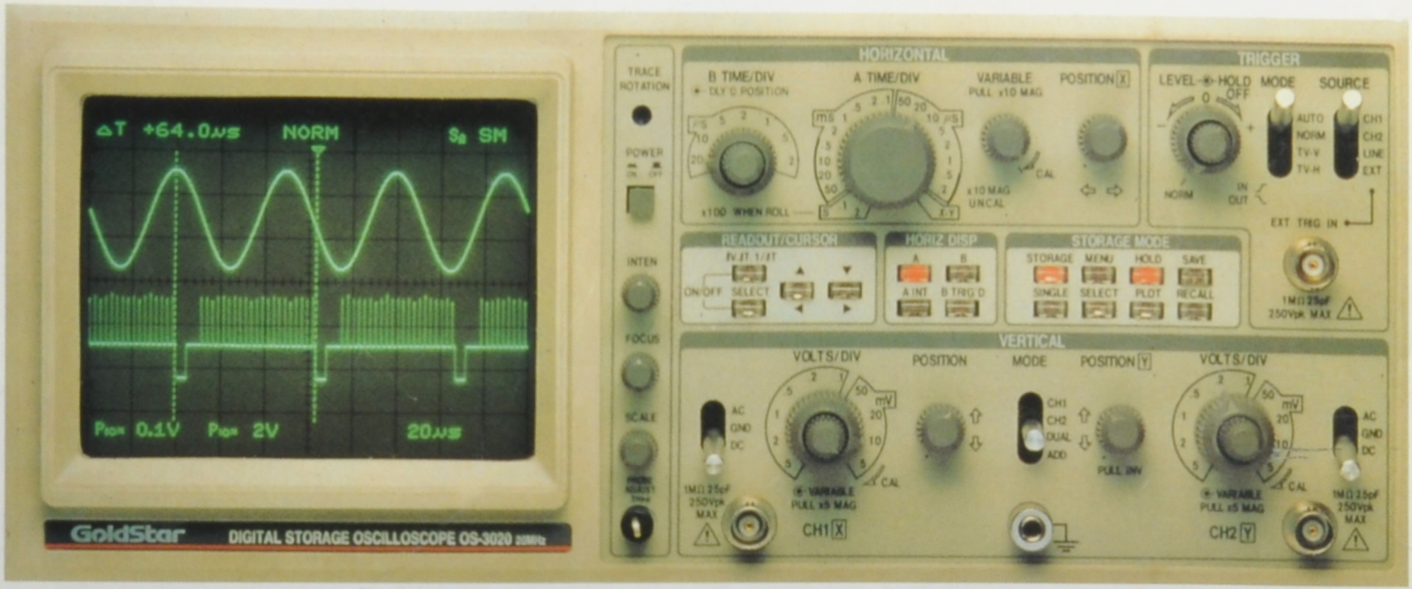

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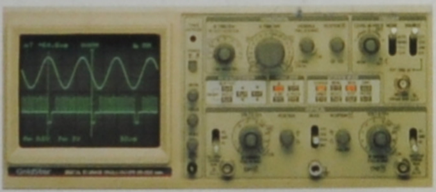

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